Appendix 5-B

Watershed-Based Stormwater Planning

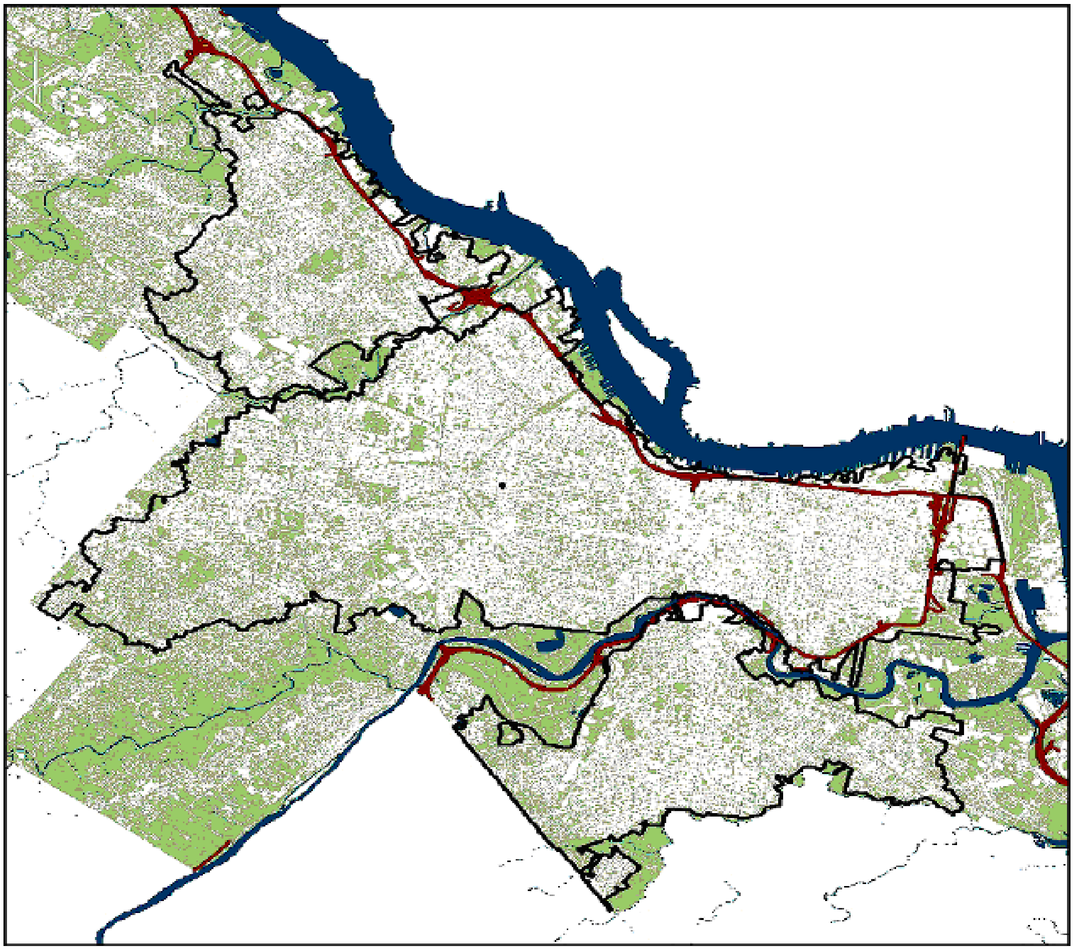

Table of Contents

CHAPTER SECTION HEADINGS

5-B.1.0	**STORMWATER MASTER PLANNING**		5-B-4
	5-B.1.1	Introduction	5-B-4
	5-B.1.2	Watershed Planning Flexibilities in the Virginia Stormwater Management Regulations	5-B-4
	5-B.1.3	Advantages of the Watershed Approach to Stormwater Management	5-B-5
	5-B.1.4	Types of Stormwater Master Planning	5-B-6
5-B.2.0	**COMPREHENSIVE WATERSHED PLANNING FOR VIRGINIA COMMUNITIES**		5-B-8
	5-B.2.1	Introduction	5-B-8
	5-B.2.2	Scale of Watershed Management	5-B-9

5-B.2.3	Elements of a Watershed Management Plan		5-B-11
5-B.2.4	The Watershed Planning Process		5-B-12
	5-B.2.4.1	Identify Initial Goals and Establish a Baseline	5-B-12
	5-B.2.4.2	Set up a Watershed Management Structure	5-B-15
	5-B.2.4.3	Determine Budgetary Resources Available for Planning	5-B-15
	5-B.2.4.4	Forecast the Type of Current and Future Development in the Watershed and Its Subwatersheds	5-B-16
	5-B.2.4.5	Defining Stressors of Concern	5-B-19
	5-B.2.4.6	Noting the Physical Constraints	5-B-19
	5-B.2.4.7	Determining Goals for Receiving Waters	5-B-19
	5-B.2.4.8	Fine-Tune Goals for the Watershed and Its Subwatersheds	5-B-19
	5-B.2.4.9	Choosing Among On-Site, Distributed, and Larger Consolidated BMPs	5-B-21
	5-B.2.4.10	Developing BMP Guidance and Performance Criteria for the Local Watershed	5-B-25
	5-B.2.4.11	Develop Watershed and Subwatershed Plans	5-B-26
	5-B.2.4.12	Establishing a Trading and Offset System	5-B-28
	5-B.2.4.13	Ensuring the Safe and Effective Performance of the Drainage Network, Streams, and Floodplains	5-B-29
	5-B.2.4.14	Establishing Community Objectives for the Publicly Owned Elements of Stormwater Infrastructure	5-B-29
	5-B.2.4.15	Establishing an Inspection and Maintenance Plan	5-B-29
	5-B.2.4.16	Adopt and Implement the Plan	5-B-30
	5-B.2.4.17	Monitor and Assess Performance	5-B-34
	5-B.2.4.18	Revisit and update the plan	5-B-35

5-B.3.0	**INTEGRATION OF SITE AND WATERSHED-LEVEL STORMWATER PLANNING**		5-B-36
	5-B.3.1	Introduction	5-B-36
	5-B.3.2	Using the Local Review Process to Ensure Compliance with Watershed Plans	5-B-36
	5-B.3.3	Integrating Watershed Plans Into Enforceable Permits	5-B-38
5-B.4.0	**INTER-JURISDICTIONAL WATERSHED PLANNING**		5-B-40
5-B.5.0	**OTHER WATERSHED PLANNING RESOURCES**		5-B-42
5-B.6.0	**CASE STUDIES**		5-B-43
	5-B.6.1	Henrico County Regional Stormwater Management Plan	5-B-43
	5-B.6.2	Chesterfield County’s Swift Creek Watershed Stormwater Management Plan	5-B-44
	5-B.6.3	Norman Oklahoma Comprehensive Watershed-Wide Stormwater Management Plan	5-B-46
	5-B.6.4	Big Darby Accord Watershed Master Plan, Columbus, Ohio	5-B-55
5-B.7.0	**REFERENCES**		5-B-61

FIGURES

Figure 5-B.1.	Watershed Management Units	5-B-10
Figure 5-B.2.	Example of a Watershed Map with Subwatersheds Delineated	5-B-13
Figure 5-B.3.	On-Site versus Regional Stormwater Management	5-B-22
Figure 5-B.4.	On-Site and Regional Stormwater Management Approaches	5-B-22
Figure 5-B.5	Big Haynes Creek Watershed	5-B-42
Figure 5-B.6.	Swift Creek Reservoir	5-B-44
Figure 5-B.7.	Streambank erosion along the Little River	5-B-47
Figure 5-B.8.	Fallen trees and debris resulting from stream erosion block a section of Imhoff Creek	5-B-47
Figure 5-B.9.	This reach of Shoal Creek was restored Using bioengineered techniques and natural materials	5-B-50
Figure 5-B.10	Big Darby Creek Watershed Planning Area	5-B-56
Figure 5-B.11	Big Darby Accord Watershed Planning System	5-B-57
Figure 5-B.12	Big Darby Watershed Conservation Strategy	5-B-58
Figure 5-B.13	Three Alternative GIS Land Use Scenarios for the Big Darby Watershed Plan	5-B-59

TABLES

Table 5-B.1	Description of New USGS Hydrologic Mapping System Units	5-B-10
Table 5-B.2	Applicability of Stormwater Control Categories by Type of Development	5-B-18
Table 5-B.3	Comparison of on-Site and Watershed Stormwater Management Approaches	5-B-25
Table 5-B.4	Example of Subwatershed Management Alternatives from a Watershed Plan	5-B-28
Table 5-B.5	Land Use Planning Techniques	5-B-32
Table 5-B.6	Potential Watershed Indicators	5-B-35
Table 5-B.7	Examples of Customized Subwatershed Management Strategies	5-B-40
Table 5-B.8	Summary of Proposed Stormwater Projects	5-B-49
Table 5-B.9	Norman, Oklahoma, Watershed Plan Project Prioritization Scoring Sheet	5-B-52
Table 5-B.10	Three Rate Options: Fiscal Year 2008-2009 Dollars (Uninflated)	5-B-55

5-B.1.0 STORMWATER MASTER PLANNING

5-B.1.1 Introduction

Stormwater master planning is an important tool with which communities can assess and prioritize both existing and potential future stormwater problems, as well as use to consider alternative stormwater management solutions. A stormwater master plan is prepared to consider, in detail, what stormwater management practices and measures are to be provided for an urban drainage area or a large development project.

Stormwater master plans are most often used to address specific single functions such as drainage provision, flood mitigation, cost/benefit analysis, or risk assessment. These plans prescribe specific management alternatives and practices. Multi-objective stormwater master planning broadens this traditional approach to potentially include land use planning and zoning, water quality, habitat, recreation, and aesthetic considerations. The broadest application of stormwater master planning is the comprehensive watershed plan which is described in detail in this Appendix.

For any stormwater master plan, it is important at the outset to: (1) clearly identify and quantify the objectives and issues the plan will address; (2) recognize the constraints (technical, political, legal, financial, social, physical) that limit the possible solutions; and (3) develop a clear technical approach that will address the key issues and needs while staying within the constraints to potential solutions.

5-B.1.2 Watershed Planning Flexibilities in the Virginia Stormwater Management Regulations

Although site-by-site compliance with stormwater management requirements is much better than no stormwater management at all, evidence from across the nation indicates that individual controls on stormwater discharges are inadequate as the sole solution for stormwater in urban watersheds. Ideally, BMP implementation needs to be designed as a system, integrating structural and nonstructural BMPs and incorporating watershed goals, site characteristics, development land use, construction erosion and sediment controls, aesthetics, monitoring and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality.

Section 4 VAC 50-60-96 of the regulations allows local governments to develop comprehensive watershed-based stormwater management plans as an alternative way to comply with the water quality requirements, the water quantity requirements, or both. State and federal agencies intending to develop large tracts of land also may develop or participate in comprehensive watershed stormwater management plans where practicable. Section 4 VAC 50-60-76 also allows linear development projects, such as streets and highways, to achieve compliance in accordance with such a watershed plan, as an alternative to strict on-site compliance.

Those who develop such plans must demonstrate to DEQ and the State Water Control Board (Board) that the results of implementing the plan will be at least as good as, if not better than, those that would be achieved from straightforward implementation of the regulation requirements on a site-by-site basis. The Board must approve local watershed plans before they may be implemented. The local program must document nutrient reductions achieved during the plan's implementation, in order to demonstrate the actual equivalence of compliance results. If the percent of impervious area upon which the plan was based changes or if any other amendments are deemed necessary by the local program, the local program must provide plan amendments to the Soil and Water Conservation Board for review and approval. For example, if the plan's target total nutrient removal for the watershed is based on an expected build-out resulting in a composite 53 percent impervious cover, and subsequently the locality approves comprehensive plan and zoning changes that will result in a composite 65 percent imperviousness at build-out, then the plan's original targets will no longer achieve results equivalent to those required in the regulations. The locality would need to amend the plan to achieve equivalence and submit the amendments to the Board for review and approval.

Section 4 VAC 50-60-63 of the regulations allows watershed plans to allow for compliance offsets (off-site mitigation, compliance trading, or fee-in-lieu options), where compliance is not feasible or cost-effective on the development site due to physical constraints, etc. In such cases, the chosen offset measure must ensure that the resulting stormwater control is equal to or greater than what would be required on each contributing land disturbing site. In fact, since the watershed planning process accounts for ultimate pollutant load reductions, such plans provide the best opportunity to optimize the most cost-effective strategy and mix of practices to achieve compliance. The regulations require that offsets must be achieved within the same Hydrologic Unit Code (HUC) watershed, or within HUCs established by the locality for this purpose. *Watershed plans also provide the best opportunity for communities to achieve an effective approach to encouraging and stimulating redevelopment and infill development and discourage continued sprawl into outlying areas.*

5-B.1.3 Advantages of the Watershed Approach to Stormwater Management

The watershed approach has the following significant advantages over traditional piecemeal approaches to stormwater management that require individual land developments to provide on-site stormwater management facilities

Lower capital and O&M Costs. Typically, comprehensive watershed management plans result in fewer and larger stormwater management facilities. Economies of scale are achievable in capital costs and especially in Operation and Maintenance costs. Strategic placement of regional facilities allows available funding to be concentrated on areas where the potential benefits are greatest. Cost sharing arrangements significantly reduce the net cost of stormwater management to the community as a whole.

Increased effectiveness on a watershed-wide basis. Often different portions of watersheds require different types of stormwater controls. Watershed planning permits the siting of a variety of on-site and regional facilities in locations where the greatest respective benefits are achieved.

Greater use of nonstructural measures. Often the most practical stormwater controls involve nonstructural measures such as land acquisition, floodplain zoning, subdivision drainage ordinances, and land use controls. Watershed planning provides a coordinated comprehensive framework and decision-making process to allow the effective implementation of these measures.

Less risk of negative "spillover" effects. The piecemeal approach may adequately solve localized drainage problems, but seldom addresses downstream impacts. Thus, the site-by-site approach raises the risk that dynamic interactions between upstream drainage improvements may actually increase downstream flooding. An objective of watershed planning is to account for these upstream interactions and achieve solutions for both localized and regional stormwater management concerns.

More flexibility in ways to satisfy regulatory criteria. Once a community has calculated the volume of water that must be "treated" to achieve the necessary reduction in pollutants, the total load to be reduced can be apportioned to a number of different kinds and scales of strategically located practices. For example, the mix of BMPs could include the following:

- Some on-site practices where this is feasible
- Fees-in-lieu of on-site practices, where achieving the required reduction is impractical or unachievable (or where development intensity – e.g., the central business district or corridor) is such that it is more cost-effective to achieve the reductions elsewhere in the watershed)
- Off-site mitigation, where the required pollutant reduction is achieved collectively on more than one site (provided applicable conditions are met)
- Regional-scale facilities
- Stormwater retrofits in previously developed areas
- Stream restoration to reduce sediment from bank erosion and bedload transport

This approach allows the community to make the best use of its land while still achieving the stormwater management goals established for the watershed.

5-B.1.4 Types of Stormwater Master Planning

There are several basic types of stormwater master plans that can be prepared. Below are descriptions of representative examples of master plans.

Flood assessment master plans. Flood assessment is the simplest form of stormwater master planning, where only the essential components, alignments, and functions of a drainage system are analyzed. The focus of these studies is on water quantity control and flood prevention and/or mitigation.

Frequently, a flood assessment study analyzes both existing conditions and projected future build-out conditions. The study is based upon estimates (usually modeled) of peak and total discharges for selected return frequency runoff events. The selected events should be based on local standards. Both the hydrology and hydraulics of the system are analyzed to determine water surface profiles and elevations. This, in turn, assists in determining probable locations where impacts can be expected to occur. Frequently, an alternatives analysis will be performed as part of the master plan to provide potential solutions to mitigating the flood impacts. This typically involves the modeling of proposed modifications or development scenarios.

Examples include examining the effects of detention on flooding and providing improved flood protection (e.g., flood proofing structures, levies, etc). A local community might develop HEC-1 and HEC-RAS models for the hydrology and hydraulics of a watershed for the purposes of estimating the full buildout floodplain and regulating new development on this basis rather than the ever-changing “existing conditions” approach.

Flood study cost/benefit analysis master plans. Another type of master planning builds on a flood assessment master plan to determine acceptable risks and the associated costs. Using information developed in the flood analysis, economic and/or environmental impacts can be assessed. This initially entails establishing a relation between water surface elevation and associated damage (often referred to as stage-damage curves). Based on this relationship, an acceptable level of risk is determined, from which design discharges and associated water surface profiles and elevations are established. Acceptable levels of risk might be based upon the likelihood of loss of human life, impacts to residences, impacts to non-residence structures, or damage to utilities. This information then helps determine the ultimate drainage infrastructure that will be needed to achieve the planning goals. Either a formal cost-benefit analysis or a more subjective “cost-effectiveness” approach could be used. Based on the design criteria, preliminary designs can be developed which in turn yield initial cost estimates for the infrastructure.

For example, a community might look at different flood protection strategies along a stream and estimate the costs and flood damage savings for each alternative in an effort to select the most appropriate solution(s) for that community.

Water quality master plans. Master planning for stormwater quality is becoming increasingly important, as nonpoint source loads are a critical component of watershed-wide water quality assessments. For many Georgia communities it is necessary to be able to estimate pollutant loads from stormwater runoff for TMDLs, as well as for the expansion of wastewater treatment facilities. A water quality master plan can provide the foundation from which to develop broader water quality assessments.

Stormwater quality studies will typically analyze water quality impacts to receiving waters (and groundwater, particularly in karst regions) and develop structural and nonstructural strategies to reduce or minimize the pollutant loads. Studies usually involve the development, calibration, and verification of a water quality model. The level of model sophistication can vary from simple to complex. Often, a cost/benefit analysis will be performed as a component of the water quality study to quantify the efficacy of various strategies.

For example, a community might develop a simple spreadsheet-based loading model to perform planning level analyses of loadings of pollutants, potential removal by stormwater controls, and the impacts of development strategies – or they use a more complex continuous simulation water quality model and supporting monitoring to develop a combination of point and non-point source loading estimates in support of a watershed assessment or TMDL.

Biological/habitat master plans. Biological/habitat master planning is similar to a water quality master plan. However, rather than focusing on water chemistry, the focus is on the aquatic biological communities and supporting habitats. Biological assessments are being implemented on a more frequent basis to assess overall water body health. Biological studies provide the ability to assess both acute and long-term effects of nonpoint source impacts to a receiving water in the absence of continuous monitoring data. The resulting data can be used in the design and development of habitat improvement and stream restoration projects, riparian buffers, structural control retrofits, etc.

For example, a community may desire to improve the quality and aesthetics of a stream. Biological monitoring and habitat assessment establishes the baseline health of the stream and can be compared to a reference stream in the area. This information is assessed to determine causes of impairment (often paired with chemical monitoring) and methods to reduce impairment are investigated. The plan might then include riparian corridor planning, land use zoning changes, and planned habitat restoration.

Comprehensive watershed master plans. The comprehensive watershed approach is the most general type of stormwater master planning as well as the most extensive. The intent of comprehensive watershed plan is to assess existing water resources health and to make informed land use and stormwater planning decisions based on the current and projected land use and development within the targeted watershed and its associated subwatersheds. Watershed-based water quantity and water quality goals are typically aimed at maintaining the pre-development hydrologic and water quality conditions to the extent practicable through peak discharge control, volume reduction, groundwater recharge, channel protection, and flood protection. In addition, watershed plans may also promote a wide range of additional goals include the streambank and stream corridor restoration, habitat protection, protection of historical and cultural resources, enhancement of recreational opportunities, and aesthetic and quality of life issues.

Watershed-based studies often involve a holistic approach to master planning, where hydrology, geomorphology, habitat, water quality, and biological community impacts are analyzed and solutions are developed. A detailed discussion of watershed-based master planning is provided below.

5-B.2.0 COMPREHENSIVE WATERSHED PLANNING FOR VIRGINIA COMMUNITIES

5-B.2.1 Introduction

Due to the realization that urban stormwater quantity and quality management need to be addressed at a larger scale, communities are increasingly turning towards the development of comprehensive watershed and subwatershed plans. These plans usually encompass broader management issues such as land use planning and zoning, recreational and aesthetic opportunities, water supply protection, and habitat management.

5-B.2.2 Scale of Watershed Management

Watersheds are typically defined according to the resource area or downstream water body of interest. Although there are no maximum size limits for defining a watershed, a manageable watershed for local planning efforts is usually no greater than 100,000 acres (~150 square miles). It is important to remember that larger watershed boundaries require the involvement of more jurisdictions and stakeholders.

Ideally, planning take place at both the watershed and smaller "subwatershed" scales. Typically, the broad, "big picture" planning takes place at the watershed level, and the more refined objectives and implementation plans are pursued at a subwatershed level (see **Table 5-B.1 and Figure 5-B.1** below). Finally, individual projects and controls are carried out at the project or catchment level.

Often times it may be more efficient to plan at the watershed scale and to assess the effectiveness of plan implementation at the subwatershed scale, where indicator response is more apparent. For example, many of the non-traditional goals of a multi-objective watershed master plan, such as establishment of inter-jurisdictional greenways, wildlife corridors, and forest conservation areas, are easier to conceptualize and implement at the watershed scale.

A community undertaking a watershed planning effort will need to determine whether the project area under consideration is part of a larger watershed or river basin with its own distinct management goals. If so, the community needs to ensure that the planned activities complement the broader-scale efforts. On the other end of the scale, a local government must also make sure that development and neighborhood level stormwater management projects and activities are incorporated into and complement the overall watershed plan.

More specific information about the correlation of Virginia hydrologic unit geography with the USGS watershed mapping can be found on the Virginia Department of Conservation and Recreation website at:

http://www.dcr.virginia.gov/soil_and_water/hu.shtml

Table 5-B.1. Description of New USGS Hydrologic Mapping System Units

Order	No. Digits in New ID#	New Name	Unit Size	Sample Management Measures
1	2	Region	Avg. 177,560 sq. mi.	
2	4	Subregion	Avg. 16,800 sq. mi.	
3	6	(River) Basin	Avg. 10,596 sq. mi.	
4	8	Sub-basin	Avg. 703 sq. mi.	Basin-wide planning
5	10	Watershed [1]	Range: 40,000 acres (62.5 sq. mi.) to 250,000 acres (390+ sq. mi.)	Basin-wide planning combined with watershed-based development standards
6	12	Subwatershed	Range: 10,000 acres (15+ sq. mi.) to 40,000 acres (62.5 sq. mi.)	Watershed-based development standards combined with stream classification and management
		Catchment [2]	Avg. Range: 5 - 15 sq. mi.	Stream classification and management
		Subcatchment [2]	Avg. Range: 0 - 5 sq. mi.	Site design measures and structural controls

NOTES:
[1] 100,000 acres or 150 sq. mi. may be the upper practical local planning limit
[2] These terms are not part of the new USGS classification system, but they may help local planners develop more discrete planning units

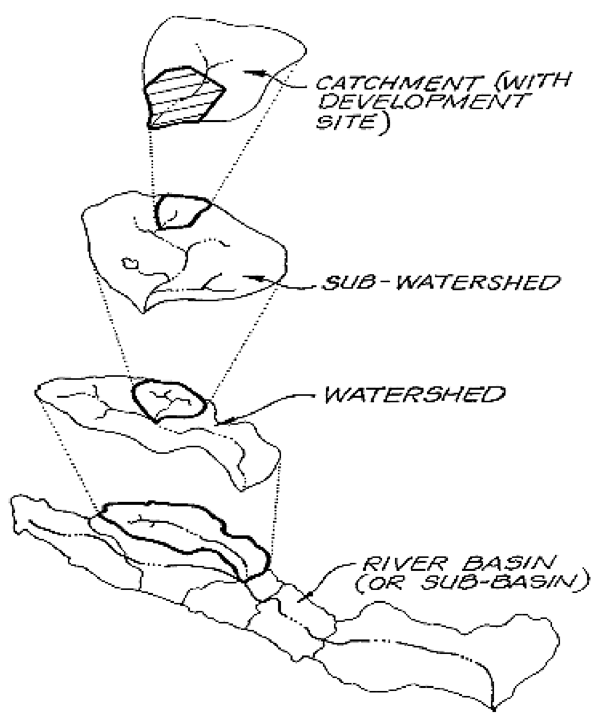

Figure 5-B.1. Watershed Management Units
Source: Center for Watershed Protection (1998)

5-B.2.3 Elements of a Watershed Management Plan

Watershed management plans should include recommended criteria for stormwater source controls and treatment practices in the watershed. These criteria are based on watershed-specific factors such as physical attributes, land use, pollution sources, and sensitive receptors. The criteria are the basis for selecting and locating stormwater controls in the watershed. At a minimum, a watershed management plan should contain the following elements to address stormwater-related issues:

- Watershed delineation and identification of watershed characteristics such as topography, soils, surficial geology, impervious cover, and land use (current and projected)
- Inventory of flood hazard areas as identified by FEMA Flood Insurance Studies or the Virginia Department of Conservation and Recreation (DCR), plus historic floods and damages
- An evaluation of streams/watercourses, including areas of limited flow capacity, bank or bed erosion, sediment deposition, water quality, principle water uses and users, recreation areas, morphology classification, and channel stability
- An inventory and evaluation of hydraulic structures, including culverts, bridges, dams and dikes, with information on their flow capacity and physical condition
- An inventory of significant water storage areas, including principal impoundments, floodplains, and wetlands
- Identification of sensitive and impaired wetlands and water bodies
- Evaluation of functional value of wetlands to identify sensitive and high quality wetland resources
- Sensitive groundwater recharge or aquifer protection areas
- Identification of existing problem land uses and impacts on water quality
- Land use restrictions in sensitive areas
- Inventory of local wetlands, conservation, planning and zoning, and subdivision regulations of the watershed municipalities to identify potential regulatory changes for addressing stormwater impacts
- A runoff hydrograph analysis of the watershed for floods of an appropriate duration, including a 24-hour event, with average return frequencies of 2, 10, 25, and 100 years for existing and future land uses
- The relationship between the computed peak flow rates and gauging station data, with modification or calibration of the hydrographs to obtain a reasonable fit where necessary
- Identification of the peak rate of runoff at various key points in the watershed, and the relative timing of the peak flows
- Identification of points in the watershed where hydraulic structures or watercourses are inadequate under existing or anticipated future conditions
- Recommendations on how the subwatershed’s runoff can be managed to minimize any harmful downstream (flooding) impacts
- Existing and projected future pollutant loads, impacts of these loads, and pollution reduction goals
- Existing and projected aquatic habitat disturbances and goals for habitat restoration
- Recommendations for watershed-specific stormwater treatment controls, conceptual design, and operation and maintenance (O&M) needs and responsibilities
- Water quality monitoring program

- Prioritized implementation plan for recommendations
- Identification of public water supply watershed areas and identified aquifer recharge areas

The watershed management plan should address integrating flood control and stormwater management controls with community needs, including open space, aesthetics, and other environmental objectives, such as habitat and stream restoration. This synchronization with other programs can create better funding opportunities and enhance the overall benefit of the stormwater management practices in the watershed.

5-B.2.4 The Watershed Planning Process

Watershed and subwatershed plans provide a framework for managers and decision-makers to determine what the goals and strategies of the plan should be and how and where various management and protection tools need to be implemented to achieve the goals and strategies. Developing watershed and subwatershed plans should ideally occur in a rapid, cost effective manner. A 18-step approach to watershed planning is presented below. It is important to remember throughout the process that it is critical to have public involvement and "buy in." Without community support, it may be difficult to implement a plan.

5-B.2.4.1 Identify Initial Goals and Establish a Baseline

Prior to initiating a watershed plan, some broad goals should be identified that define the purpose of the plan initiative. For example, a goal of a plan may be to preserve and maintain a high quality segment of stream in a community, protect drinking water quality in a water supply watershed, or meet a water quality TMDL. Other goals may be a response to negative impacts being observed within a watershed, such as property flooding or channel erosion and degradation.

Prior to addressing the initial goals, it is necessary to gather basic information to determine a starting point to develop the plan. Information about possible stakeholders, current land use and impervious cover, technical studies (e.g., previous hydrologic/hydraulic studies, floodplain studies, water quality studies, etc.), staffing, and financial resources can help guide the first steps of the plan. Once the broad goals have been identified and defined, specific tasks that may need to be performed include the following.

Task 1: Define Watershed and Sub-Watershed Boundaries

Defining the watershed and subwatershed boundaries sets the stage for completing the rest of the watershed baseline. The product of this task is a simple map that outlines the boundaries of the watershed and each of its sub-watersheds. Producing this map (**Figure 5-B.2** below is an example) is a necessary first step to answering questions such as "Which political jurisdictions and citizens should participate in this watershed planning effort?" and "What are the land use patterns in the watershed and each of its sub-watersheds?" This establishes the scale of watershed planning, discussed in **Section 5-B.2.2** above.

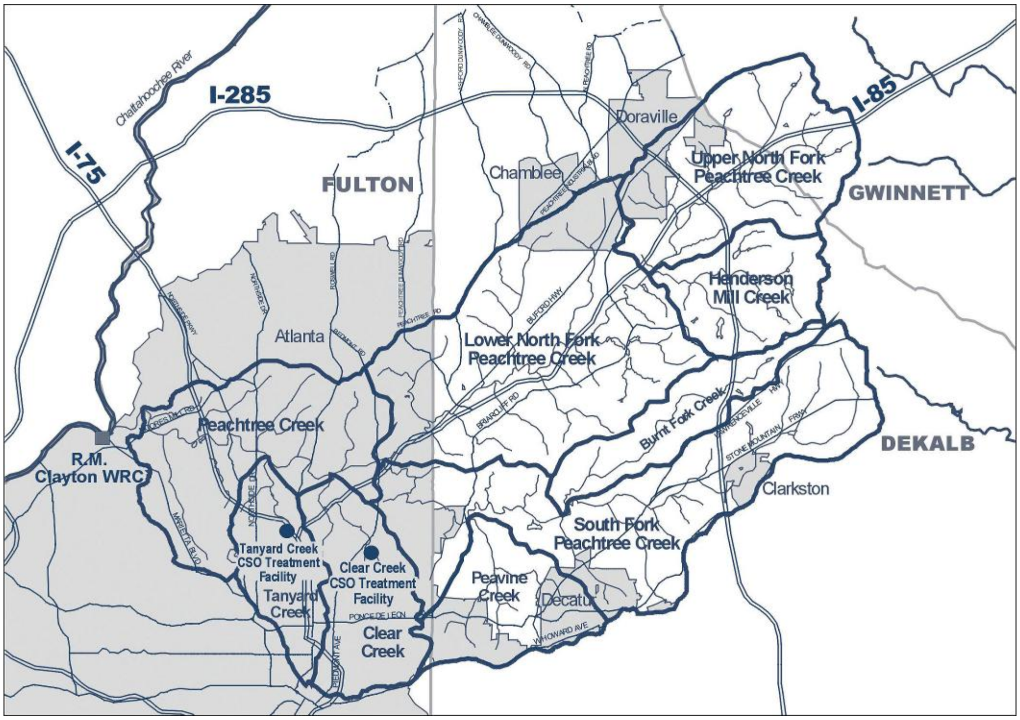

Figure 5-B.2. Example of a Watershed Map with Subwatersheds Delineated
Source: ARC (2001)

Task 2: Identify Possible Stakeholders

Early on, it is important to identify the partners, or stakeholders, that will be involved in some way to make watershed plans happen. Stakeholder involvement is discussed in more detail in **Chapter 3** of this Handbook, pertaining to development of a local stormwater management program.

Early stakeholder involvement guides the development of the watershed plan to incorporate the needs of the community and promote resource protection. By involving possible stakeholders early on in the process, managers can gage who wants to participate in developing the plan, what they can offer to the process, or what obstacles participants may present. Stakeholders might include other government agencies, businesses and industry, regulated entities, nonprofits, and neighborhood leaders and interested citizens. To effectively achieve local/regional water quality goals, it is best to take a coordinated, structured and collaborative approach, coordinating across sectors and creating alignment in policies, funding and programs to achieve a Collective Impact (Hanleybrown et al, 2012).

The watershed and subwatershed boundaries delineated in *Task 1* are a good place to start identifying possible stakeholders. A quick review of the map helps determine which jurisdictions and neighborhoods fall within the watershed boundaries. Direct outreach to citizens living within the watershed boundaries can also spark interest within the community. Stakeholders can provide resources, expertise, or knowledge to guide the development of the plan. Also, it is important to include stakeholders from the local development community since some decisions of the plan, such as new ordinances or zoning, will directly impact them. It is also wise at this time to look beyond the boundaries of the watershed under study to see how the plan may help achieve the broad water resource goals of larger river basins.

Task 3: Estimate Existing Land Use and Impervious Cover

Estimating existing subwatershed land cover is a recommended baseline task in preparing a watershed plan, since this data can be used in modeling stormwater runoff and estimating pollutant loadings. Existing impervious cover provides an estimate of current conditions in each sub-watershed and serves as an important benchmark to assess future land use changes. Land use and impervious cover percentages can be used to initially categorize sub-watersheds, help managers set expectations about what can be achieved in each sub-watershed, and guide decisions in the watershed. The Impervious Cover Model, presented in **Appendix 5-A**, may be useful in this analysis. If the analysis indicates that impervious cover will increase to such an extent that it will likely cause subwatershed quality to decline, the management plan should include provisions to mitigate these future impacts.

Task 4: Assemble Historical Monitoring Data in the Watershed

Good monitoring data that accurately characterizes the resource quality in a sub-watershed are needed throughout the watershed planning process. Historical monitoring or modeling data are often available from past efforts. Collecting historical data may significantly reduce the costs of initial baseline monitoring. Historical data may also provide information about the response of the water resource to land use change over time. This record can help managers evaluate current decisions in the context of the impacts of past decisions on the resource.

Task 5: Assess Existing Mapping Resources

Maps depicting current conditions—including land use, potential pollution sources, problem areas, etc.—in each sub-watershed, as well as management decisions made during the planning process, are an integral part of the watershed plan. The effort to produce these maps depends on what data are already mapped, and in what form. Also, some field measurements may not be required if recent maps of these features already exist.

Regional development authorities, state agencies, universities or environmental agencies may already have some maps, either in paper or digital form. The Virginia Geographic Information Network (VGIN) website (http://gisdata.virginia.gov/Portal/) is a good source of existing digital GIS data. Stakeholders are also a source to find existing mapping resources. Assigning one individual or a small group the task of assembling and manipulating mapping data is an effective way to set this baseline.

Task 6: Conduct an Audit of Local Watershed Protection Capability

The final element of the watershed baseline is a critical evaluation of the local capability to implement watershed protection tools and management alternatives. This evaluation or audit examines whether existing local programs, regulations, and staff resources are capable of implementing the watershed plan. If not, it identifies key areas that need to be improved. The scope of the audit can include an analysis of local master plans, ordinances, the development review process, performance criteria for stormwater controls and management practices, program funding, and staffing levels. The effort needed for the watershed audit depends to a great extent on the size and complexity of the local program(s), the number of staff employed, and the pace of development activity.

5-B.2.4.2 Set Up a Watershed Management Structure

Establish the institutional organization responsible for the overall management and implementation of the watershed plan. Choosing the most effective watershed management structure to guide the development of the watershed and subwatershed plans is one of the more complex decisions a community or watershed planning team confronts. Successful watershed planning requires a strong organization to act as the driving force to focus the resources of a diverse group of stakeholders to implement the plan.

It is crucial to choose a watershed management structure that can be sustained over the life of the watershed planning and implementation process, as well as to revisit and update the plan as project goals are achieved or circumstances change.

A core set of features are needed to make watershed management structures effective:

- Adequate permanent staff to perform facilitation and administrative duties
- A consistent, reliable, long-term funding source to ensure a sustainable organization
- Including all stakeholders in planning efforts
- A core group of individuals dedicated to the project who have the support of local governmental agencies
- Local ownership of the watershed plan fostered throughout the process
- A process for monitoring and evaluating implementation strategies
- Open communication channels to increase cooperation between organization members

The first two features, permanent staffing and adequate long-term funding to support them, are probably the most important. Regardless of the size, a successful management structure should define inter-agency and governmental partnerships and agreements needed to support the organization over the long term.

5-B.2.4.3 Determine Budgetary Resources Available for Planning

Conduct an analysis to determine what level of staffing, financial and other resources are available to develop and implement the plan. Balance the available resources against the estimated cost of developing the plan.

One of the most important challenges confronting a community or watershed planning group is how to develop watershed and subwatershed plans within existing budget constraints. The watershed planning team needs to identify what sources of funding are available and to develop budgets for the subwatershed and watershed plans. Several current and future revenue sources may be available to finance the development of a watershed plan. This revenue may include both staff time and general funds. In early meetings, it is important to get clear commitments from each involved agency or group as to what resources they can commit to the watershed planning effort. Substantial savings can be realized if volunteers are available to conduct some of the analyses, if existing staff time is reallocated to work on the plan, or if the plan is part of a larger planning effort where some costs can be shared. Also, keep in mind that grants from local professional and business organizations may be feasible, since those entities may ultimately benefit from more comprehensive and flexible implementation of stormwater management at the watershed scale.

5-B.2.4.4 Forecast the Type of Current and Future Development in the Watershed and Its Subwatersheds

Forecasting the type of current and future development within the local watershed will ultimately influence how individual BMPs will be implemented at each individual site. The broad development categories that are generally thought of include (1) *Greenfield Development* (small and large scales), which changes pristine or agricultural land to urban or suburban land uses (frequently low-density residential housing); (2) *Redevelopment* within established communities and on Brownfield sites, which changes an existing urban land use to another, usually of higher density; and (3) *Retrofitting,* which is not truly a development type, but rather an opportunity to upgrade stormwater management within an existing urban land use and drainage infrastructure to meet higher stormwater management standards. Forecast future development, land use, and impervious cover in each subwatershed. This analysis will influence the goal setting process in *Step 8*

As previously mentioned, land use in a watershed and its individual subwatersheds has a strong influence on water quality and aquatic ecosystems. In this step, it is recommended that the community forecast future land use and impervious cover based on available planning information, such as future land use plans or master plans. In Virginia, such a forecast will typically be associated with the community's comprehensive land use plan.

Greenfield Development. Greenfield development requires new infrastructure designed according to contemporary design standards for roads, utilities, and related infrastructure. At the largest scale, Greenfield development refers to planned communities at the developing edge of metropolitan areas, ranging from several hundred acres to tens of thousands of acres with long build-out schedules. They often include the trunk (primary) stormwater system as well as open stream and river corridors. The most progressive communities of this type incorporate a significant portion of the area to stormwater systems that exist as surface elements. Such stormwater system elements are typically at the subwatershed scale and provide for consolidated conveyance, detention, and water quality treatment. These elements of the infrastructure can be multi-functional in nature, providing for wildlife habitat, trail corridors, and open-space amenities.

Greenfield development can also occur on a small scale – neighborhoods or individual sites within newly developing areas that are served by the larger public and smaller site-by-site stormwater systems. This smaller scale, incremental expansion of existing urban patterns is a more typical way for cities to grow. A more limited range of BMPs and innovative stormwater management practices is available on smaller projects of this type, including what are referred to as LID practices.

Redevelopment. Redevelopment refers to developed areas undergoing land use change. In contrast to Greenfields, infrastructure in previously developed areas is often in poor condition, was not built to current design standards, and is inadequate for the new land uses proposed. Furthermore, the existing infrastructure is often fixed in space in a manner that limits the site layout of the redevelopment project. Redevelopment within established communities is typically at the scale of individual sites and occasionally the scale of a small district. The area is usually served by private, on-site systems that convey larger storm events into pre-existing stormwater systems that were developed decades ago, either in historic city centers or in "first ring," post-World War II suburbs adjacent to historic city centers. Redevelopment in these areas is typically much denser than the original use. The resulting increase in impervious area, and typically the inadequacy of existing stormwater infrastructure serving the site often results in significant development costs for on-site detention and water quality treatment. Elaborate vaults or related structures, or land area that could be used for development, must often be committed to on-site stormwater management to comply with current stormwater requirements.

Brownfields are redevelopments of industrial and often contaminated property at the scale of an individual site, neighborhood, or district. Secondary public systems and private stormwater systems on individual sites typically serve these areas. In many cases, especially in outdated industrial areas, little or no stormwater infrastructure exists, or it is so inadequate as to require replacement. Water quality treatment on contaminated sites may also be necessary. For these reasons, stormwater management in such developments presents special challenges. For example, the most common methods of remediation of contaminated sites involve capping of contaminated soils or treatment of contaminants in situ, especially where removal of contaminated soils from the site is cost-prohibitive. Given that contaminants are still often in place on redeveloped Brownfield sites and must not be disturbed, installing certain BMPs (e.g., infiltration of stormwater into site soils) or excavating for stormwater piping and other utilities presents special challenges.

Each type of development has a different characteristic footprint, level of impervious cover, amount of open space, land cost, and existing stormwater infrastructure. Consequently, BMPs that are ideally suited for one type of development may be impractical or infeasible for another. As might be expected, there are more options available for managing stormwater in Greenfield development than at redevelopment sites, and more options in redevelopment than for retrofitting existing urban areas.

Table 5-B.2 below shows which broad BMP categories (from **Table 5.1 of Chapter 5**) are best suited for Greenfield development (particularly low-density residential), redevelopment of urban areas, and intense industrial redevelopment, which requires a substantially different suite of BMPs than for urban development.

Table 5-B.2. Applicability of Stormwater Control Categories by Type of Development

Stormwater Control Category	Low-Density Greenfield Development	Urban Redevelopment	Intense Industrial Redevelopment
1. Product Substitution	Sometimes	Often	Often
2. Watershed and Land-Use Planning	Always	Always	Sometimes
3. Conservation of Natural Areas	Always	Rarely	Sometimes
4. Impervious Cover Minimization	Always	Rarely	Rarely
5. Earthwork Minimization	Always	Rarely	Rarely
6. Erosion and Sediment Control	Always	Always	Always
7. Reforestation and Soil Conservation	Always	Often	Often
8. Pollution Prevention SCMs for Hotspots	Rarely	Often	Always
9. Runoff Volume Reduction – Rainwater Harvesting	Always	Always	Often
10. Runoff Volume Reduction – Vegetated	Always	Sometimes	Often
11. Runoff Volume Reduction – Subsurface	Always	Sometimes	Rarely
12. Peak Reduction and Runoff Treatment	Always	Rarely	Sometimes
13. Runoff Treatment	Sometimes	Sometimes	Always
14. Aquatic Buffers and Managed Floodplains	Often	Rarely	Sometimes
15. Stream Rehabilitation	Sometimes	Rarely	Rarely
16. Municipal Housekeeping	Sometimes	Sometimes	NA
17. Illicit Discharge Detection and Elimination	Sometimes	Sometimes	Sometimes
18. Stormwater Education	Often	Often	Often
19. Residential Stewardship	Always	Often	NA

Source: NRC (2008)

Forecasting the Scale of Current and Future Development. The choice of what BMPs to use depends on the area that needs to be serviced. It turns out that some BMPs work best over a few acres, whereas others require several dozen acres or more. Some are highly effective only for the smallest sites, while other work best at the stream corridor or subwatershed level. **Table 5.1 of Chapter 5** includes a column (entitled "Where") that is related to the scale at which individual BMPs can be applied. The BMPs mainly applied at the site scale include runoff volume reduction (e.g., rainwater harvesting and vegetated), runoff treatment (e.g., settling, filtering, and biological uptake) and pollution prevention BMPs (especially at hotspots). As one goes up in scale, BMPs like runoff volume reduction (both vegetated and subsurface), earthwork minimization, and erosion and sediment control take on a more prominent role. At the largest scales, watershed and land-use planning, conservation of natural areas, reforestation and soil conservation, peak flow reduction, buffers and managed floodplains, stream rehabilitation, municipal housekeeping, illicit discharge detection and elimination (IDDE), stormwater education, and residential stewardship play a more important role. Some BMPs are useful at all scales, such as product substitution and impervious cover minimization.

5-B.2.4.5 Defining Stressors of Concern

The primary pollutants or stressors of concern (and the primary source areas or stormwater hotspots within the watershed likely to produce them) should be carefully identified for the watershed. Although the Virginia Stormwater Management Regulations dictate certain keystone pollutant removal criteria, it is important that the community ensure that BMPs are designed to prevent or reduce the maximum load of pollutants of greatest concern locally, as well, especially where TMDL waste load allocations are in place. The choice of pollutants of concern is very important, since individual BMPs have been shown to have highly variable capabilities to prevent or reduce specific pollutants.

5-B.2.4.6 Noting the Physical Constraints

The specific physical constraints of the watershed terrain and the development pattern will influence the selection and assemblage of BMPs. The application of BMPs must be customized in every watershed to reflect its unique terrain (such as karst, high water tables, shallow or steep slopes, freeze-thaw depth, soil types, and underlying geology). Each BMP has different restrictions or constraints associated with these terrain factors. Consequently, the BMP prescription changes as one moves from one physiographic region to another (e.g., the flat coastal plain, the rolling Piedmont, the ridge and valley, and mountainous headwaters).

5-B.2.4.7 Determining Goals for Receiving Waters

It is important to set biological and public health goals for the receiving water(s) that are achievable given the ultimate impervious cover intended for the local watershed. If the receiving water is too sensitive to meet these goals, one should consider adjustments to zoning and development codes to reduce the amount of impervious cover. The biological goals may involve a keystone species (e.g., trout, crabs, cave-adapted invertebrates, etc.); a desired state of biological integrity in a stream; or a maximum level of eutrophication in a lake. In other communities, stormwater goals may be driven primarily by the need to protect a sole-source drinking water supply, cave streams, or karst springs, or to maintain water contact recreation at a beach, lake or river. Once again, the watershed goals that are selected have a strong influence on the assembly of BMPs needed to meet them, since individual BMPs vary greatly in their ability to achieve different biological or public health outcomes.

5-B.2.4.8 Fine-Tune Goals for the Watershed and Its Subwatersheds

Use known information about impacts to the watershed, and the goals of larger drainage units (e.g., river basins), to refine and develop goals for the watershed. In addition, determine objectives for each subwatershed to achieve the broader watershed goals. The general goals identified in *Step 1* should be added to and modified to reflect the results and inferences of the data collected and analyses performed in *Steps 2-7*.

Goal setting is among the most important steps in watershed planning, and the management structure should ensure full involvement from stakeholders at this stage. Goal setting should proceed from the broad basin and sub-basin goals to the more specific goals needed for the watershed. These goals, in turn, need to be translated into even more specific objectives for each individual sub-watershed. To set appropriate and achievable goals, the watershed planning team needs to perform the following tasks.

Task 1: Interpret Goals at the River Basin Level that May Impact the Watershed

Watershed plans should be developed within the context of regional water resource management goals for river basins. Although not every river basin goal or objective may impact the watershed plan, managers should be aware of the larger basin plans, and consider them when developing their own goals and objectives. Some examples of river basin goals that may directly influence the goal setting process at the watershed level include:

- Flood control
- Meeting state water quality standards / designated use
- Meeting Chesapeake Bay or other impaired stream TMDL requirements
- Wildlife habitat enhancement
- Greenway establishment

Task 2: Develop Specific Goals for the Watershed

The goals set at the watershed level are the "bottom line" of the watershed plan. While these goals may be similar to those developed at the river basin level, they are usually more specific and quantifiable. Examples of watershed goals include:

- Reduce flood damage from current levels
- Reduce pollutant loads from the current level (or to meet an established threshold)
- Maintain or enhance the overall aquatic diversity in the watershed
- Maintain or improve the current channel integrity in the watershed
- Prevent development in the floodplain
- Allow no net loss of wetlands
- Maintain a connected buffer system/green space throughout the watershed
- Accommodate economic development in the watershed
- Promote public awareness and involvement

These goals apply to the watershed as a whole, but may not always apply to every sub-watershed within it. In addition, a watershed plan may have more unique multi-objective goals, such as developing a trail system for walking, biking, and jogging, preserving historically significant areas, and establishing outdoor education programs to foster community awareness and involvement. With diverse goals such as these, the importance of broad-based stakeholder involvement becomes all the more apparent.

Task 3: Assess if Sub-Watershed Management Objectives Can Be Met with Existing Zoning

Controlling and managing land use is an important tool to meet watershed management objectives. If a target development or impervious cover goal has been established for a watershed, managers will need to review current zoning and/or projected future land use to determine if these goals can be met. One method is to conduct a build-out analysis of current zoning to determine the projected land use and/or impervious cover in each sub-watershed. This analysis can be used to identify which management objectives can be met with existing zoning.

Task 4: Determine if Land Use Patterns Can Be Shifted Among Watersheds

If the current zoning is not compatible with the management objectives, development may need to be shifted to other watersheds or subwatersheds. One way to accomplish this goal is by upgrading the zoning in watersheds that are designated to accommodate growth, while down-zoning those watersheds that exceed the management goals or to which other land management goals may apply (e.g., preserving prime agricultural land). The effect is to shift development away from the streams and other water resources that will be most impacted by development, and toward areas where there is not as great of an impact (e.g., redevelopment/revitalization areas where urban infrastructure already exists). Other possible options include preserving undisturbed conservation areas (e.g., through land trusts, conservation easements, etc.) in a watershed, or by implementing strategies to reduce impervious cover.

The process described above is not simple. While controlling land use may be the most effective way to protect watersheds and sub-watersheds, it can also be the most controversial and politically-charged recommendation in a watershed or sub-watershed plan. Any change in zoning will require input from citizens, the development community, and local government. Furthermore, actually changing zoning can take a long time. Communities will need to use the legal tools they have available (e.g., transfer of development rights, overlay zones, floating zones, etc.) to change zoning appropriately.

5-B.2.4.9 Choosing Among On-Site, Distributed, and Larger Consolidated BMPs

Using individual, on-site structural stormwater controls for each development is the typical approach in most communities for controlling stormwater quantity and quality, as is described in **Chapter 5**. The developer finances the design and construction of these controls and, initially, is responsible for all operation and maintenance. However, after construction is completed, the local government is likely to become responsible for maintenance activities if the owner fails to carry them out. A potential alternative approach is for a community to install a few strategically located regional stormwater controls in a sub-watershed rather than require on-site controls (see **Figures 5-B.3 and 5-B.4** below). Watershed management plans can identify conditions and locations in the watershed where regional stormwater management facilities may be more appropriate or effective than on-site controls for both stormwater quality and quantity controls.

For this Handbook, regional (watershed) stormwater controls are defined as facilities designed to manage stormwater runoff from multiple projects and/or properties through a local jurisdiction-sponsored program, where the individual properties may assist in the financing of the facility, and the requirement for on-site controls is either eliminated or reduced.

Historically the on-site approach to stormwater management has been more common in Virginia. In this approach, land developers have responsibility for deploying treatment practices and runoff controls at individual development sites. Developers are responsible for constructing on-site stormwater management facilities to control stormwater pollutant loadings and the volume and flow rate of runoff from the site. The local government is responsible for reviewing the design of stormwater management facilities relative to specified design criteria, inspecting the constructed facilities to ensure conformance with the design, and ensuring that operation and maintenance plans are provided and implemented for the facilities. The on-site approach addresses stormwater pollution close to its source, offers greater opportunities to preserve pre-development hydrologic conditions, and reduces the overall volume of stormwater runoff.

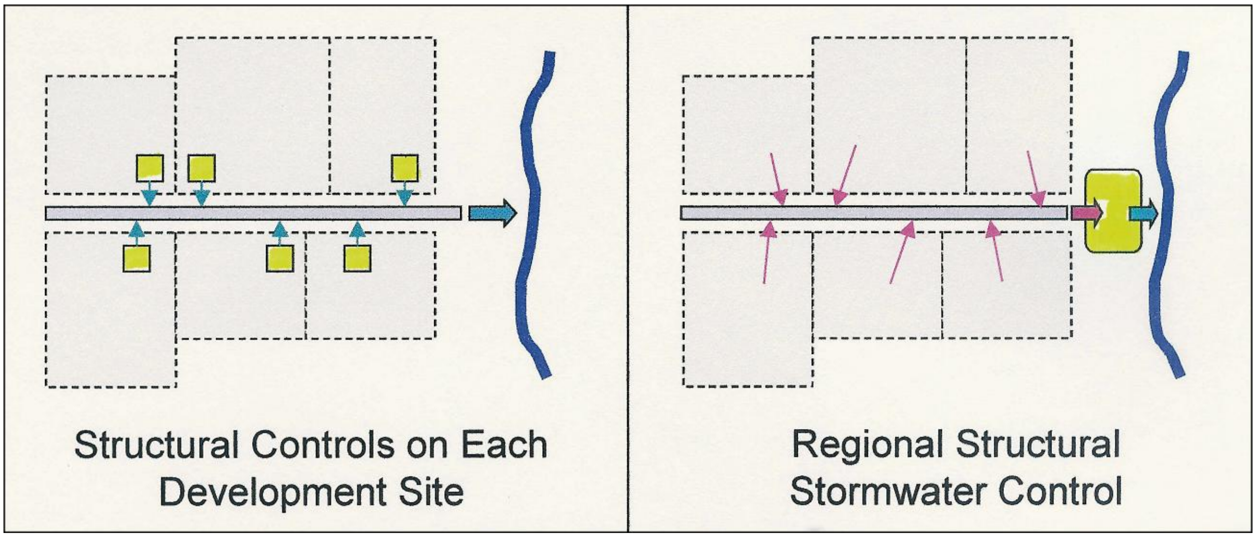

Figure 5-B.3. On-Site versus Regional Stormwater Management
Source: ARC (2001)

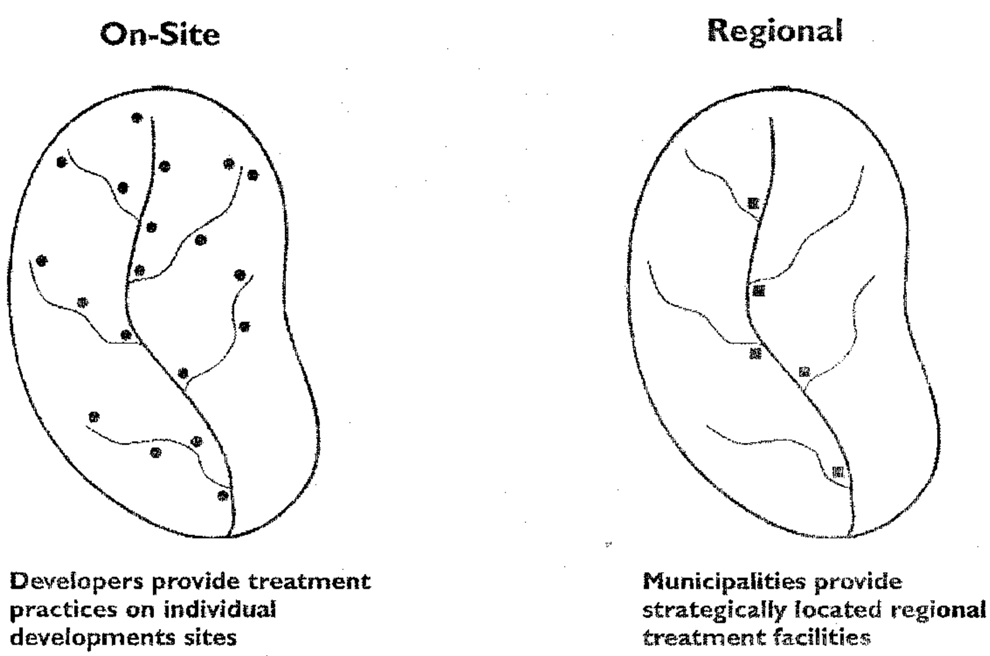

Figure 5-B.4. On-Site and Regional Stormwater Management Approaches
(Source: Adapted from Novotny, 1995, and Connecticut 2004 Stormwater Quality Manual)

The watershed approach involves strategically siting stormwater management facilities to control stormwater runoff from multiple development projects or large drainage areas. Most of the advantages of the watershed approach can be attributed to the need for fewer stormwater management facilities that are strategically located throughout the watershed (Novotny, 1995). Local or regional governments assume the capital costs for constructing the regional facilities. Design and construction of regional controls are estimated to cost from $1,250 to $2,000 per acre of residential development and $1,750 to $2,500 per acre of non-residential development. Capital costs are typically recovered from upstream developers as development occurs. Individual regional facilities are often sited and phased in as development occurs according to a comprehensive watershed management plan. Municipalities generally assume responsibility for operation and maintenance of regional stormwater facilities (Novotny, 1995).

There are also several disadvantages to regional stormwater controls that have limited the widespread use of the watershed approach, including significant required advanced planning, financing, and land acquisition.. In many cases, a community must provide capital construction funds for a regional facility, including the costs of land acquisition, before the majority of the watershed is developed, with reimbursement by developers over build-out periods of many years (WEF and ASCE, 1992).. However, if a downstream developer is the first to build, that person could be required to construct the facility and later be compensated by upstream developers for the capital construction costs and annual maintenance expenditures. Conversely, an upstream developer may have to establish temporary control structures if the regional facility is not in place before construction.

Maintenance responsibilities generally shift from the homeowner or developer to the local government when a regional approach is selected. Because consolidated facilities are typically larger than on-site BMPs, mechanized maintenance equipment can be used, allowing for greater efficiency and lower costs. However, the local government may need to establish a stormwater utility or some other program to fund and implement stormwater control.

Due to these limitations, the watershed approach generally is more appropriate for (Pennsylvania Association of Conservation Districts et al., 1998):

- Highly developed watersheds with severe water quality and flooding impacts, where stormwater controls for new development alone cannot adequately address the impacts in these areas; and
- Watersheds where the timing of peak runoff may increase downstream flooding if on-site peak runoff attenuation criteria are applied uniformly throughout the watershed.

If a community decides to implement a regional stormwater control, then it must ensure that the conveyances between the individual upstream developments and the regional facility can handle the design peak flows and volumes without causing adverse impact or property damage. Full build-out conditions in the regional facility drainage area should be used in the analysis. In addition, unless the system consists of completely man-made conveyances (i.e. storm drains, pipes, concrete channels, etc.), then on-site structural controls for water quality and downstream channel protection may still need to be required for all developments within the regional facility's drainage area.

Federal water quality provisions do not allow the degradation of water bodies from untreated stormwater discharges, and it is USEPA policy to not allow regional stormwater controls that would degrade stream quality between the upstream development and the regional facility. Further, without adequate channel protection, wetlands, aquatic habitats and water quality in the channel network upstream of a regional facility may be degraded by streambank erosion, if they are not protected from bankfull flows and high velocities. Based on these concerns, both the EPA and the U.S. Army Corps of Engineers have expressed opposition to *in-stream* regional stormwater control facilities. In-stream facilities should be avoided if possible and will likely be permitted on a case-by-case basis only.

In most watersheds, a mix of regional and on-site controls is desirable and has the greatest potential for success when implemented as part of a comprehensive watershed management plan. (DEP, 1995). Both approaches have a number of advantages and disadvantages, which are summarized in **Table 5-B.3** below**.**

Based on the foregoing factors and using state-established BMP design specifications as a foundation, the community could consider adapting specific sizing, selection, and design requirements for BMPs, ensuring that the adaptations achieve equivalent water quality and quantity management results. The Virginia Stormwater Management Law allows localities to adopt criteria more *stringent* than the State’s criteria within certain parameters. The regulations also allow localities to disallow the use of some BMPs within their jurisdictions, subject to certain conditions. However, if adaptations are made, these need to be coordinated with the DEQ and, ultimately, approved by the State Water Control Board.

Resulting BMP performance criteria may be established in a local or regional stormwater design manual or by reference in a local watershed management plan. In general, the watershed- or receiving water-based criteria are more specific and detailed than would be found in the State-established criteria. For example, the local stormwater guidance criteria may be more prescriptive with respect to runoff reduction and BMP sizing requirements, outline a preferred sequence for BMPs, and indicate where BMPs should (or should not) be located in the watershed. Like the identification of stressors or pollutants of concern, this step is rarely taken under current paradigms of stormwater management. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how BMP guidance can be customized to protect specific types of receiving waters (e.g., high quality lakes, trout streams, drinking water reservoirs, and impaired waters).

Table 5-B.3. Comparison of on-Site and Watershed Stormwater Management Approaches

Approach	Advantages	Disadvantages
On-site	• Requires much less (and less involved) advanced planning • Addresses stormwater pollution close to its source~~,~~ thereby reducing the volume of stormwater runoff and the need for treatment controls • Provides greater groundwater recharge benefits • Private ownership and maintenance responsibility is an advantage to the community (less responsibility and cost)	• Results in a large number of facilities that may not be adequately maintained by developers, homeowners or HOAs • Consumes more on-site land that could be used for other purposes • May increase downstream flooding and quantity control problems • Encourage lower-density development and, thus, urban-suburban sprawl • Less opportunity to treat off-site (e.g., streets and ROWs) runoff • Limited opportunities to treat previously developed land without BMPs
Watershed	• Generally more cost-effective than numerous individual on-site controls • Reduced capital costs through economies of scale in designing and constructing regional facilities • Reduced operation and maintenance costs because there are fewer facilities to maintain • Greater reliability because communities are more likely to ensure long-term maintenance of regional facilities • Nonpoint source pollutant loadings from existing developed areas can be affordably controlled at the same regional facilities that are sited to control future development • Maximize the use of developable land by minimizing the amount of land that must be set aside for stormwater control measures • Can be integrated with local greenway networks • Regional facilities provide greater opportunities for multi-purpose uses that also provide recreational and aesthetic benefits, flood control, and wildlife habitat and corridors • Can be used to treat runoff from public streets, which is often missed by on-site facilities • Provides opportunities for retrofit practices to reduce regional stormwater pollutant loadings and provides a schedule for implementing appropriate controls • Less safety risk than for on-site controls – more visible, easier to secure	• Significant advanced planning and, perhaps, permitting required • Regulatory hurdles regarding proposed *in-stream* BMPs • May be difficult to site due to larger facility size and limited land availability • Requires up-front financing (land acquisition, design and construction) • May promote “end-of-pipe” treatment mentality rather than the use of on-site controls to reduce stormwater runoff volume and the need for stormwater treatment • Without on-site BMPs, regional BMPs do not protect smaller streams (upstream from the regional facilities) from degradation and streambank erosion • Upstream inundation from regional BMPs can eliminate floodplains, wetlands and other habitat • Greater administrative responsibility for local governments • Lack of adequate training for local staff needed to administer such a program • Some treatment practices are not appropriate for large drainage areas (e.g., swales, filter strips, media filters, and oil/particle separators, etc.) • Potential for different standards applicable in neighboring jurisdictions within the same watershed • Some safety or liability concerns for larger, regional facilities

Source: Adapted from NRC (2008)

5-B.2.4.10 Developing BMP Guidance and Performance Criteria for the Local Watershed

Based on the foregoing factors and using state-established BMP specifications as a foundation, the community could consider adapting specific sizing, selection, and design requirements for BMPs, ensuring that the adaptations achieve equivalent water quality and quantity management results.

Within certain parameters, the Virginia Stormwater Management Act allows localities to adopt criteria *more stringent* than the State's criteria. The regulations also allow localities to disallow the use of some BMPs within their jurisdictions, subject to certain conditions. However, if adaptations are made, these need to be coordinated with the DEQ and, ultimately, approved by the State Water Control Board. Resulting BMP performance criteria may be established in a local or regional stormwater design manual or by reference in a local watershed management plan.

In general, the watershed- or receiving water-based criteria will be more specific and detailed than the State-established BMP design specifications. For example, the local stormwater guidance criteria may be more prescriptive with respect to local precipitation amounts for various design storms, runoff reduction and BMP sizing requirements, outline a preferred sequence for BMPs, and indicate where BMPs should (or should not) be located in the watershed. Like the identification of stressors or pollutants of concern, this step is rarely taken under current paradigms of stormwater management. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how BMP guidance can be customized to protect specific types of receiving waters (e.g., high quality lakes, trout streams, drinking water reservoirs, and impaired waters).

5-B.2.4.11 Develop Watershed and Subwatershed Plans

A watershed plan is a detailed blueprint to achieve objectives established in the last step. A typical plan may include: revised zoning, stormwater design criteria and requirements, potential regional structural stormwater control locations, description of new programs proposed, stream buffer widths, monitoring protocols, and estimates of budget and staff needed to implement the plan. Tasks needed to establish the watershed plan include the following four.

Task 1: Select Watershed Indicators

Indicator monitoring provides timely feedback on how well aquatic resources respond to management efforts. Simple indicators can be selected to track changes in stream geometry, biological diversity, habitat quality, and water quality. For example, macroinvertebrate sampling is a relatively quick and inexpensive method to assess biological diversity. It can also be used to qualitatively assess aquatic habitat and water quality. This type of monitoring can be done by citizen volunteer networks, to minimize the expense (e.g., the Save-Our-Streams program and Virginia Citizen Monitoring Network, affiliated with the Virginia Department of Environmental Quality). A wide range of indicators can be used to assess the performance of management plans. The most appropriate indicators will depend largely on the management categories of the individual watersheds.

Task 2: Conduct Watershed-Wide Analyses and Surveys, if Needed

In some situations, a watershed plan may need to incorporate special analyses at the watershed level to supplement basic monitoring and analyses. A manager may decide to include a flood management analysis, pollutant load reduction analysis, or recreational greenway analysis. Other analyses that may be desirable include the following:

- Fishery and habitat sampling
- Stream reconnaissance surveys
- Stormwater structural control performance monitoring
- Bacteria source surveys
- Stormwater outfall surveys
- Detailed wetland identification
- Pollution prevention surveys
- Nutrient budget calculations
- Surveys of potential contaminant source areas
- Hazardous materials surveys
- Stormwater retrofit surveys
- Shoreline littoral surveys
- In-lake monitoring
- Hydro-geologic studies to define surface/groundwater interactions

Task 3: Prepare Sub-Watershed and Aquatic Corridor Management Maps

Maps that present the plan in a clear, uncomplicated manner are a key product of the sub-watershed planning process. Maps range from highly sophisticated GIS maps to simple overlays of USGS quadrangle sheets. Mapping can generally be conducted at two scales, the subwatershed scale and the aquatic corridor scale.

Subwatershed maps represent an entire subwatershed on a single map and should be a component of all watershed plans. These maps represent the natural features and institutional information needed to produce a watershed plan. Aquatic corridor maps are produced at a much finer scale than sub-watershed maps, and represent only the area immediately adjacent to the stream corridor or shoreline. Aquatic corridor maps are highly recommended, particularly when stream buffers or floodplain development limits are an important consideration in the watershed plan.

Task 4: Adapt and Apply Watershed Protection Tools

Just as different goals need to be established depending on a watershed's management category, so do the various tools used to protect that resource. For example, while structural stormwater controls are recommended as a component of all management plans, the types of controls used will be different depending on the specific characteristics of a given watershed. An example of a watershed plan presenting different management control alternatives for its sub-basins is shown in **Table 5-B.4**.

Table 5-B.4. Example of Subwatershed Management Alternatives from a Watershed Plan

Subbasin/Scenario	Control Alternative													
	Stormwater Detention	Quantity (ac)	Streambank Restoration	Quantity (lf)	Riparian Zone Restoration	Quantity (lf)	Pool Development	Quantity (each)	Upland Water Quality Detention	Enhanced Erosion Control	Major Creek Clean-up	Enhanced Removal of Illicit Connections	Development Controls	Capital Cost ($M)
Upper North Fork Peachtree Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem	X	120	X	286,740	X	430,110	X	70				X		51.2
Henderson Mill Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem	X	58	X	66,685	X	80,020								18.7
Lower North Fork Peachtree Creek Subbasin														
Scenario 1-Rehab Tribs with Industrial Source Control	X	212	X	250,300	X	216,925	X	264	X		X	X		78.7
Scenario 2-Rehab Tribs and Main Stem	X	212	X	313,315	X	271,540	X	442			X	X		78.3
Burnt Fork Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem	X	50	X	73,070	X	77,130					X	X		18.5
Peavine Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem			X	58,815	X	67,860	X	75						2.2
South Fork Peachtree Creek Subbasin														
Scenario 1-Rehab Main Stem	X	189	X	24,885	X	62,215	X	104						54.9
Scenario 2-Rehab Tribs and Main Stem	X	189	X	61,890	X	92,515	X	124						56.6
Tanyard Creek Subbasin (Stormwater Area)														
Scenario 1-Rehab Tribs	X	17	X	10,880	X	24,175	X	0		X		X		5.2
Scenario 2-Rehab Tribs and Main Stem	X	17	X	17,580	X	39,060	X	48		X		X		5.5
Clear Creek Subbasin (Stormwater Area)														
Scenario 1-Rehab Tribs	X	32	X	27,230	X	17,020	X	0		X		X		10.7
Scenario 2-Rehab Tribs and Main Stem	X	32	X	48,485	X	30,300	X	22		X		X		12.0
Peachtree Creek Subbasin														
Scenario 1-Rehab Main Stem	X	120	X	67,540	X	75,045	X	167				X		37.1
Scenario 2-Rehab Tribs and Main Stem	X	120	X	97,305	X	223,875	X	228				X		38.9

Note: ac = acre; lf = linear foot; $M = million dollars
- Pool development involves the placement of boulders in the stream to allow the formation of pools downstream of the boulder cluster.
- "0" value indicates that alternative was found to be impractical due to intermittent flows.

Source: ARC (2001)

5-B.2.4.12 Establishing a Trading and Offset System

A stormwater trading or offset system is a critical option for situations when on-site BMPs are not feasible or desirable in the watershed. Communities may choose to establish some kind of stormwater trading or off-site mitigation system in the event that full compliance is not possible on-site due to physical constraints or because it is more cost-effective or equitable to achieve pollutant reductions elsewhere in the local watershed. The most common example is providing an offset/in-lieu fee based on the cost to remove an equivalent amount of the target pollutant(s) (such as phosphorus here in Virginia). This kind of trading can provide for greater cost equity between low-cost Greenfield sites and higher-cost ultra-urban sites.

5-B.2.4.13 Ensuring the Safe and Effective Performance of the Drainage Network, Streams, and Floodplains

The urban water system is not solely designed to manage the quality of runoff. It also must be capable of safely handling flooding from extreme storms to protect life and property. Consequently, communities need to ensure that their stormwater infrastructure can prevent increased flooding caused by development (and possibly exacerbated future climate change). In addition, many BMPs must be designed to safely pass extreme storms when they do occur. This usually requires a watershed approach to stormwater management to ensure that quality and quantity control are integrated together, with an emphasis on the connection and effective use of conveyance channels, streams, riparian buffers, wetlands and floodplains.

In fact, in more undeveloped watersheds, consideration should be given to protecting the riparian corridors (streams, wetlands, and floodplains) from development encroachment and, where feasible, restoring degraded streams and wetlands. As Ian McHarg taught and practiced decades ago, this allows the natural system to function as nature intended – as the primary stormwater management system for the watershed. These corridors can be integrated into the community's public green space (parks, trails, recreation areas, etc).

5-B.2.4.14 Establishing Community Objectives for the Publicly Owned Elements of Stormwater Infrastructure

The stormwater infrastructure in a community normally occupies a considerable surface area of the landscape, once all the SCMs, drainage easements, buffers, and floodplains are added together. Consequently, communities may require that individual BMP elements are designed to achieve multiple objectives, such as landscaping, parks, recreation, greenways, trails, habitat, sustainability, and other community amenities (as discussed extensively above). In other cases, communities may want to ensure that BMPs do not cause safety or vector problems and that they look attractive. The best way to maximize community benefits is to provide clear guidance in local BMP criteria at the site level and to ensure that local watershed plans provide an overall context for their implementation.

5-B.2.4.15 Establishing an Inspection and Maintenance Plan

The long-term performance of any BMP is fundamentally linked to the frequency of inspections and maintenance. As discussed in **Chapter 9** of this Handbook, lack of regular inspections and maintenance is truly the weak element of effective, on-going stormwater management. Without it, the considerable investment of time and money in BMPs is wasted after the fact. One can imagine the results if a person neglects to inspect and maintain the systems that sustain his or her home (water supply, sewage disposal, heating and air conditioning, landscaping, etc.) or automobile (tires, lubricants, coolant, brakes, engine parts, etc.). In short order, these very expensive investments would begin to break down and lose substantial value. The same is true of investments in our stormwater management systems, which serve individual homeowners, subdivisions and communities.

As a result of the historic lack of maintenance, Virginia's SWM regulations permit conditions for industrial, construction, and municipal permittees specify that all BMPs must be adequately maintained. MS4 communities are also required under NPDES stormwater permits to track, inspect, and ensure the maintenance of the collective system of BMPs and stormwater infrastructure within their jurisdictions. In larger communities, this can involve hundreds or even thousands of individual BMPMs located on either public or private property. In these situations, communities need to devise a workable model that will be used to operate, inspect, and maintain the stormwater infrastructure across their local watershed.

Communities have the lead responsibility in their MS4 permits to assure that BMPs are maintained properly to ensure their continued function and performance over time. They can elect to assign the responsibility to the public sector, the private sector (e.g., property owners, homeowners associations or contractors), or a hybrid of the two. But under their MS4 permits, they have ultimate responsibility to ensure that BMP maintenance actually occurs. This entails assigning legal and financial responsibilities to the owners of each BMP in the watershed, as well as maintaining a tracking and enforcement system to ensure compliance. Maintenance should be a primary consideration in the watershed plan, which provides an opportunity to achieve significant overall cost-efficiencies.

5-B.2.4.16 Adopt and Implement the Plan

The best ways to ensure that a watershed plan is effectively implemented are to involve the right stakeholders, realistically assess budgetary resources, develop a scientifically and economically sound plan, and mandate its use in the development process. A good plan in itself does not guarantee implementation. As the plan is being developed, and afterwards, watershed planners need to work to ensure that the local government has both the regulatory authority and the resources to implement the plan. It is important that the plan is not isolated from other government planning and construction activities.

Once a watershed management plan has been developed, a community requires the necessary means to implement the plan and accomplish its goals. Watershed plan implementation is an involved process that requires the simultaneous consideration of many issues. Implementation of the recommendations of a local watershed management plan can take place through a number of related mechanisms. The following mechanisms can be used to implement watershed plan goals. Each of these mechanisms will generally be used in some form in every watershed, but their application will most likely vary from one community or one watershed to the next.

- ***Stormwater Ordinance.*** In some communities the watershed or master plan is adopted (often by reference) in its stormwater ordinance and essentially becomes an overlay district wherein development decisions must follow plan recommendations for various parts of the watershed. In others it is not mandatory, but is referred to when rezoning and plan approval decisions are made by staff and zoning boards. Compliance is monitored through the plan review and approval process, construction inspections, and oversight of long-term BMP maintenance.

- ***Environmental Site Design Techniques.*** A community can promote a suite of environmental site design practices and techniques (see **Chapter 6** of this Handbook) to reduce the amount of stormwater runoff and pollutants generated in a watershed, as well as to provide for non-structural treatment and control of runoff. The watershed plan should specify which environmental site design techniques are most applicable in individual sub-watersheds to meet the plan's goals and objectives.
- ***Land Acquisition and Conservation.*** Land acquisition and land conservation are important elements of any watershed management program. They allow a community to protect critical environmental areas and stormwater management resources. There are several techniques that can be used to conserve land, which provide a continuum ranging from absolute protection to very limited protection. Representative land conservation techniques include land purchases, land donations, conservation easements, and public sector stewardship.
- ***Land Use Planning / Zoning.*** Zoning and land use planning are the most widely used tools for managing growth and development that communities have at their disposal. Comprehensive plans can be modified to incorporate the recommendations of the watershed or stormwater master plan into long-term land use planning, transportation plans, etc., and then referred to when rezoning and plan approval decisions are made by staff and zoning boards. Parks and open space plans can use the results of the plan to ensure the multi-objective nature of the plans are implemented, combining engineering functions with aesthetics and recreational opportunities. This can be used to preserve sensitive areas, maintain or reduce the impervious cover within a given sub-watershed, and redirect development toward sub-watersheds that can support a particular type of land use and/or density. A wide variety of land use planning and/or zoning techniques can be used to manage land use and impervious cover within a watershed. The more commonly used techniques are summarized in **Table 5-B.5** below.
- ***Riparian Buffers and Greenways.*** The creation of a riparian buffer system is key in mitigating flood impacts and protecting water quality and streambanks in urban areas. Technically speaking, a buffer is a type of land conservation area, but it has added importance in a stormwater management sense in its ability to provide water quality, flood prevention and channel protection benefits. Buffers create a natural "right of way" for streams that protect aquatic ecosystems and provide a safe conduit for potentially dangerous and damaging floodwaters. Buffers provide water quality benefits and protection for streams, rivers and lakes. Buffers also serve as valuable park and recreation systems that enhance the general quality of life for residents. Finally, buffers can provide valuable wildlife habitat and act as wildlife corridors for smaller mammals and bird species that are present in urban areas. Establishing a comprehensive and contiguous buffer system, or "greenway," should be a goal of virtually all watershed plans. To achieve this goal, effective and clear guidance and enforcement must occur at the site level, especially for smaller headwater streams.
- ***Computer Modeling.*** Some communities use the computer models of the drainage system developed in a watershed or master plan in a real-time format as tools to assist in decision making about the need for detention, downstream impact assessment, zoning approvals, etc. and also to track management and maintenance of the drainage infrastructure.

Table 5-B.5. Land Use Planning Techniques

Land Use Planning Technique	Description	Use as a Watershed Protection Measure
Watershed-Based Zoning	Zoning restrictions specific to a particular watershed or subwatershed	Can be used to protect water resources in a particular watershed and/or relocate development
Overlay Zoning	Superimposes additional regulations or specific development criteria within specific mapped districts	Can require development restrictions or allow alternative site design techniques in specific areas
Impervious Overlay Zoning	Specific overlay zoning that limits total impervious cover within mapped districts	Can be used to limit potential stormwater runoff and pollutants from a given site or watershed
Performance Zoning	Specifies a performance requirement that accompanies a zoning district	Can be used to require additional levels of performance within a watershed or at the site level
Large-Lot Zoning	Zones land at very low densities	May be used to decrease impervious cover at the site or subwatershed level, but may have an adverse impact on regional or watershed imperviousness and may promote urban sprawl
Transfer of Development Rights (TDRs)	Transfers potential development from a designated "sending area" to a designated "receiving area"	May be used in conjunction with watershed-based zoning to restrict development in specified areas and encourage developing in areas capable of accommodating increased densities
Limiting Infrastructure Extensions	A conscious decision is made to limit or deny extending infrastructure (e.g., public sewer, water, roads) to designated areas to avoid increased development there; OR may allow extension of infrastructure into the designated areas if specific (e.g., sustainability) requirements are met.	May be used as a temporary method to limit or manage growth or incentivize desirable development techniques and features in a targeted watershed or subwatershed.

Source: ARC (2001)

- ***Elimination of Non-Stormwater Discharges.*** In some watersheds, non-stormwater discharges (e.g., combined sewer overflows, or CSOs, and grey water from commercial entities) and illicit connections to storm sewers can contribute significant pollutant loads to receiving waters. Key program elements in a watershed plan include inspections of private septic systems, repair or replacement of failing systems, using more advanced on-site septic controls, identifying and eliminating illicit connections from municipal stormwater systems, and preventing toxic chemical and fuel spills.
- ***Capital Improvement Plan.*** Elements of the local long-term capital improvement plan can be derived from the recommendations of the watershed management plan. Special assessment districts, fee-in-lieu charges, system development charges, or other funding mechanisms can be established to help pay for specific improvements identified in the plan.

- ***Watershed Stewardship Programs.*** The goal of watershed stewardship is to increase public understanding and awareness about the watershed plan and goals. A watershed public information and education program strives to increase stakeholder awareness of their role in the protection of water resources, promote better stewardship of private lands, and develop reliable funding to sustain watershed management efforts. Basic programs that communities should consider to promote greater watershed stewardship include the following:
    - Watershed and stormwater/nonpoint source pollution education
    - Pollution prevention
    - Adopt-a-Stream programs
    - Watershed maintenance and cleanup activities
- ***Inter-Staff Management Team.*** An ad hoc inter-staff team is often effective in coordinating the provisions of the plan across local government departments.

Budget and Funding.

As with the watershed planning process, a serious challenge confronting a community is how to implement watershed and sub-watershed plans within existing budget constraints. The implementation of a watershed plan typically costs about 10 times as much as the planning process. As part of the planning effort, the watershed planning team will need to identify the stable and reliable sources of funding that are available and develop budgets for both the subwatershed and watershed plan implementation efforts. One of the greatest costs of watershed implementation is the staff resources needed to continue monitoring in the watershed, design and build structural controls and retrofits, and enforce the ordinances and laws that might be called for in the plan. Many of the local program funding mechanisms discussed in **Section 3.1.15 of Chapter 3** of this Handbook are also applicable to watershed plan implementation efforts.

Stakeholder Involvement

Stakeholder involvement and interaction is essential to the implementation of watershed plans. A citizen advisory committee (CAC) is an important feature of an effective watershed management structure. A typical CAC is open to broad citizen participation and provides direct feedback to the management structure on public attitudes and awareness in the watershed. Meaningful involvement by a CAC is often critical to convince the community and elected leaders of the need for greater investment in watershed protection.

Some of the possible functions of a citizen's advisory committee are as follows:

- Organize media relations and increase watershed awareness:
    - Press releases
    - Informational flyers
    - Watershed awareness campaigns
    - Liaison between citizen groups and government agencies
- Provide input on workable stewardship programs
- Coordinate programs to engage watershed volunteers, such as:
    - Stream monitoring
    - Stream clean-ups
    - Adopt-a-Stream programs

  - Tree planting days
  - Storm drain stenciling
- Explore funding sources to support greater citizen involvement

Another common feature of an effective watershed management structure is the reliance on a technical advisory committee (TAC) to support the overall watershed planning effort. A TAC is routinely made up of a public agency staff and independent experts who have expertise in scientific matters. Some of the possible functions of a technical advisory committee are as follows:

- Evaluate current and historic monitoring data and identify data gaps
- Coordinate agency monitoring efforts within the watershed to fill these gaps
- Interpret scientific data for the whole watershed management organization
- Assess and coordinate currently approved implementation projects

Various recommendations in a watershed plan may be implemented through non-profit citizen groups who "adopt" the watershed. These groups can be instrumental in gaining public acceptance and involvement, carrying out the recommendations of the plan, obtaining funding, and providing surveillance and reporting of watershed activities.

5-B.2.4.17 Monitor and Assess Performance

There are several different monitoring techniques or indicators that can be used to assess the performance of a watershed plan. The range of monitoring extends from the more complex chemical or toxicity testing methods to more simplified physical or biological techniques. **Table 5-B.6** below provides a list of watershed monitoring techniques or indicators that can be used in watershed monitoring, as well as the initial planning process. The list covers a wide range of alternatives that can be used to assess positive and/or negative trends in water quality, aquatic integrity and watershed health.

Regardless of the specific indicators selected, it is important to use scientifically valid assessment techniques, quality controls, and valid sampling protocols to ensure that results are repeatable, consistent, and compatible with other data collection efforts.

To effectively monitor the performance of the watershed plan, it is recommended that water quality and biological monitoring be performed on an aggregate basis at key locations in the watershed and not on a site-by-site basis. Monitoring for the NPDES MS4 program and numerous other studies have confirmed the extreme variability of stormwater quality and physical stream/habitat conditions due to many influencing factors. These factors are most variable at a single individual site. At the larger watershed level, however, some of the variability is dampened, allowing for a better evaluation of plan implementation on stream and watershed health.

Table 5-B.6. Potential Watershed Indicators

Indicator Category	Potential Indicators
Water Quality Indicators	• Water quality pollutant monitoring • Toxicity testing of contaminants • Non-point source loadings • Frequency of water quality violations • Sediment contamination • Human health criteria
Biological Indicators	• Fish assemblage • Macro-invertebrate assemblages • Single species indicator • Composite indicators • Other biological indicators
Programmatic Indicators	• Number of illicit connections identified/ corrected • Number of structural controls installed, inspected • Permitting and compliance
Physical and Hydrological Indicators	• Stream widening/downcutting • Physical habitat changes affecting biodiversity • Impacted dry weather flows • Increased flooding frequencies • Stream temperature changes
Social Indicators	• Public attitude surveys • Industrial/commercial pollution prevention • Public involvement and monitoring • User perception
Site Indicators	• Structural control performance monitoring • Industrial site compliance monitoring

Source: ARC (2001)

5-B.2.4.18 Revisit and update the plan

Periodically update the plan based on new development in the watershed or results from monitoring data. A one-time watershed study only identifies what problems exist in a watershed. Many local governments, for one reason or another, take on watershed planning without realizing that it is an ongoing process rather than a report.

Each subwatershed or watershed plan should be prepared with a defined management cycle of 5-7 years. Individual plan elements should be prepared in an alternating sequence, so that a few are started each year with all plans within a given region or jurisdiction ideally being completed within a 5-7 year time span. This is similar to how many communities update their comprehensive land use plans. A management cycle helps balance workloads of watershed staff and managers, by distributing work evenly throughout the cycle’s time period.

5-B.3.0 INTEGRATION OF SITE AND WATERSHED-LEVEL STORMWATER PLANNING

5-B.3.1 Introduction

Integrating site level development and watershed level planning can be a significant institutional challenge. It is likely that local governments will need to reevaluate their standard operating procedures for stormwater management and evolve towards a less compartmentalized mentality that strives for open communication between departments and agencies. In addition, interjurisdictional cooperative efforts are often needed, where communication and consensus building among stakeholders is critical.

Many local stormwater programs already have both development requirements and watershed level planning components. However, the challenge is to develop a set of incentives and/or requirements that site planners and engineers will adopt and follow in order to comply with watershed level planning efforts. In addition, watershed plans should be developed and implemented in a manner that considers the potential adverse impacts of site development. In other words, watershed protection measures should coincide with the development cycle (i.e., planning, design, construction, and post-construction).

5-B.3.2 Using the Local Review Process to Ensure Compliance with Watershed Plans

An important, yet frequently overlooked, task facing local regulators and plan reviewers is to ensure that local review requirements are tied to the watershed plan. There are several opportunities during the site development process where local regulators can check for agreement and consistency with existing watershed plans.

The final plan submittal and review, permit acquisition, and recordation of the final plat are mandatory steps. The requirement of an as-built plan submittal at the end of the project is strongly recommended, since this information demonstrates ultimate compliance and is important documentation for the long-term BMP maintenance process. However, both developers and local governments will find that participating in the other opportunities will generally result in better quality plans and minimize the risk of mistakes and potential compliance and enforcement issues. These checks serve as an enforcement mechanism for watershed plan implementation. The following are five key review occasions:

- Pre-consultation Meeting and Joint Site Visit
- Stormwater Management Concept Plan Submittal
- Preliminary / Final Stormwater Site Plan Submittal
- Permit Acquisition
- Final Record / As-Built Plat

These recommended checkpoints are directly applicable to the procedure for preparing and reviewing stormwater management site plans that is described in more detail in **Appendix 6-A** of **Chapter 6** of this Handbook. By utilizing this series of checkpoints throughout the local review process, communities can help to ensure that existing watershed plans are consistently referred to and that necessary measures can be taken to comply with the goals and objectives of the plans. Multiple checkpoints also provide some assurance that the sometimes diverse goals and objectives of a watershed plan are adequately reviewed by qualified and appropriate regulators.

Pre-consultation Meeting and Joint Site Visit. The primary purpose of this checkpoint is to ensure that the proposed land use of the development project is consistent with the goals and objectives of the watershed plan. This step allows the local review authority to outline any specific stormwater management requirements from the watershed plan, as well as any opportunities for site resource conservation and improved stormwater management on the development site and within the subwatershed.

Stormwater Management Concept Plan Submittal. It is recommended that a stormwater management concept plan be prepared, reviewed, and approved by the local review authority. At this review checkpoint, qualified staff should ensure that the preliminary designs being proposed not only meet all of the on-site stormwater management requirements of the local jurisdiction, but that the plan also considers broader issues associated with applicable watershed plans. For example, if fecal bacteria loads are a concern within the watershed, the plan reviewer should look to see that proposed stormwater control practices have a demonstrated ability to provide adequate bacteria removal. From a flood control standpoint, the reviewer would ensure that there are no conflicts with the proposed development and mapped floodplain boundaries from the watershed plan.

Preliminary/Final Stormwater Site Plan Submittal. At this checkpoint, the local review authority must confirm that the proposed stormwater management system from the concept plan has been adequately designed and analyzed to meet the watershed plan goals. For example, a watershed plan may have structural stormwater control maintenance goals. If maintenance agreements are not already a component of the local stormwater management criteria, this would be a case where the reviewer could require specific maintenance conditions for the development.

Permit Acquisition. There are a host of permits that may be required for a development project, such as clearing and grading, building, construction NPDES erosion and sediment control, wetlands, floodplain, etc. The permitting stage is another important checkpoint to ensure consistency with watershed plans, as permitting authorities are often part of a separate local department. In some cases, permitting will involve state and federal agencies (e.g., Corps of Engineers 404 wetlands permits). By definition, there are criteria that must be met for a permit to be issued; however, it should not be presumed that these criteria are consistent with, or as stringent as, the goals and objectives of a watershed plan.

In some cases, it may be desirable to have conditions attached to a permit so that the goals of the watershed plan can be met. For example, a watershed may have historically experienced significant sediment loading from uncontrolled construction sites, and consequently, a goal of the watershed plan is to promote construction site phasing by limiting the amount of contiguous cleared area to a specified number of acres. Under this scenario, the issuer of the clearing and grading permit might place a condition on the permit that restricts the amount of land cleared at a given time.

Final Record/As-Built Plat. A final method to ensure that the goals of a watershed plan are being implemented at the site level through the review process is to record any significant easements, buffers, or resource protection areas on the final record plat or as-built (i.e., legal document). This helps to maintain important protection areas through any land acquisition or transfer deals. Protection areas that might be recorded on a final plat include conservation easements, riparian buffer zones, and other open space conservation areas.

5-B.3.3 Integrating Watershed Plans Into Enforceable Permits

The planning, engineering, and regulatory responses to stormwater management issues are not as effective when applied independently. They are much more effective when they are applied integrally in the context of a local watershed plan. The mere existence of a plan does not result in effective stormwater management unless it is fully implemented. Relatively few watershed protection or restoration plans have progressed into actual implementation, primarily because there is no mechanism for accountability and enforcement. The clear implication is that local subwatershed plans should ideally be translated into a long term watershed-based permit to ensure implementation. The best permitting vehicle appears to be the municipal NPDES stormwater permit system. With some adaptation, these permits can be implemented on a subwatershed basis, using the process outlined below:

Step 1. Define interim water quality and stormwater goals (i.e., pollutants of concern, biodiversity targets) and the primary pollutant source areas and hotspots that cause them.

Step 2. Delineate subwatersheds within community boundaries.

Step 3. Measure current and future impervious cover within individual subwatersheds.

Step 4. Establish the initial subwatershed management classification using ICM.

Step 5. Undertake field monitoring to confirm or modify individual subwatershed classifications.

Step 6. Develop customized management strategies within each subwatershed classification that will guide or shape how land use decisions are made at the subwatershed level, and how watershed practices will generally be assembled at individual sites.

Step 7. Undertake restoration investigations to verify restoration potential in priority subwatersheds.

Step 8. Agree on the specific implementation measures that will be completed within the permit cycle. Evaluate the extent to which each of the six minimum management practices can be applied in each subwatershed to meet municipal objectives.

Step 9. Agree on the maintenance model that will be used to operate or maintain the stormwater infrastructure, assign legal and financial responsibilities to the owners of each element of the system, and develop a tracking and enforcement system to ensure compliance.

Step 10. Define the trading or offset system that will be used to achieve objectives elsewhere in the local watershed objectives in the event that full compliance cannot be achieved due to physical constraints.

Step 11. Establish sentinel monitoring stations in select subwatersheds to measure progress towards goals.

Step 12. Revise subwatershed management plans in the subsequent NPDES permitting cycle, based on monitoring data.

The core of the approach is to customize management strategies for each class of subwatershed so as to apply the most appropriate planning, engineering and regulatory tool (see **Table 5-B.7** below). The benefit of subwatershed-based permits is that it also provides accountability mechanism in the form of compliance monitoring on a subwatershed basis. In all subwatersheds, it makes sense to measure and track changes in both impervious cover (IC) created and impervious cover treated. Within individual subwatersheds, however, the focus of monitoring efforts may differ. For example, monitoring of biological metrics is recommended in sensitive and impacted streams to ensure they are meeting their objectives. Outfall monitoring continues to be important for non-supporting streams (i.e., no biological diversity), particularly if stormwater quality data are compared to action levels to identify the most polluted subwatersheds for greater treatment.

Managing urban watersheds can be challenging. The best chance of achieving stream quality objectives arises when the many tools of watershed protection and restoration are organized and aligned in the context of a stream classification system based on the Impervious Cover Model (**Appendix 5-A**) and an enforceable watershed-based permit system is established to implement them. The proposed approaches outlined in this chapter are intended to be an initial guide to help local managers to shift to a new subwatershed approach.

Table 5-B.7. Examples of Customized Subwatershed Management Strategies

Subwatershed Management Issue	Sensitive Streams (2 to 10% IC)	Impacted (IC 10 to 24%)	Non-Supporting (IC 25 to 59%)	Urban Drainage (60% + IC)
Land Use Planning and Zoning	Extensive land conservation and acquisition to preserve natural land cover. Site-based or watershed IC caps	Reduce IC created for each zoning category by changing local codes and ordinances	Encourage redevelopment, and intensification of development to decrease per-capita IC utilization in the landscape. Develop watershed restoration plans to maintain or enhance aquatic resources	
Site-Based Stormwater Reduction and Treatment Objectives	Treat runoff from two year design storm using practices to achieve 100% runoff reduction volume	Treat runoff from one year design storm using practices to achieve 75% runoff reduction volume	Treat runoff from the 90% annual storm and achieve at least 50% runoff reduction volume	Treat runoff from the first flush storm and achieve at least 25% runoff reduction volume
Site-Based IC Fees	Establish Excess IC Fee for projects that exceed IC zoning category		Allow IC Mitigation Fee	Allow IC Mitigation Fee
Subwatershed Trading	Receiving Area for Conservation Easements, Restoration Projects and Retrofit		Receiving or Sending Area for Retrofit	Sending Area, for Restoration Projects
Stormwater Monitoring Approach	Measure in-stream metrics of biotic integrity	Track subwatershed IC and measure practice performance	Check outfalls and measure practice performance	Check municipal action levels at outfalls
TMDL Approach	Protect using anti-degradation provisions	IC-based TMDLs that use flow or IC as a surrogate for traditional pollutants	Pollutant TMDLs to identify problem subwatersheds	Pollutant TMDLs to identify priority source areas
Dry Weather Water Quality	Check for failing septic system	Outfall and channel screening for illicit discharges	Dry weather sampling in streams and outfall screening	Dry weather sampling in receiving waters
Addressing Existing Development	Ensure farm, pasture and forest best practices are used	Stream repairs, riparian reforestation & residential stewardship	Storage retrofits and stream repairs	Pollution source controls and municipal housekeeping

5-B.4.0 INTER-JURISDICTIONAL WATERSHED PLANNING

Because watershed boundaries do not coincide with political jurisdictions, more than one city or county may need be involved in watershed planning efforts. Cross-jurisdictional cooperation is likely to become more important as the USEPA considers requiring local MS4 permit programs to be implemented on a watershed-by-watershed basis. Successful watershed management can only occur if all jurisdictions within a watershed boundary are involved at some level and committed to the same set of goals.

The challenge is to develop effective inter-jurisdictional watershed plans that are pro-active, well-defined, well-funded, and adequately staffed. The key ingredients to meet the challenge are as follows:

- Develop a broad-based consensus for the need to protect and manage the specified watershed. Establish a memorandum of understanding (MOU) or a memorandum of agreement between interested/concerned jurisdictions and agencies.
- Obtain some level of funding commitments from signatory parties.
- Establish a technical committee to develop and coordinate watershed management efforts.
- Consistently evaluate and update the watershed plan efforts.

An example of an inter-jurisdictional watershed planning effort is the Big Haynes Watershed Protection Program. The Big Haynes Creek Watershed is an 82 square mile watershed located about 20 miles east of Atlanta in Gwinnett, Newton, Rockdale and Walton Counties (see **Figure 5-B.5**). The watershed drains into the Big Haynes Reservoir, the water supply source for Rockdale County and the city of Conyers.

The reservoir watershed was urbanizing rapidly and faced pollution problems from stormwater runoff. Rockdale County provided protection measures for the creek, which was first identified as a possible water source in the 1970’s, by establishing three-acre minimum zoning in the proposed reservoir watershed. However, a major obstacle to protection is that about 76 percent of the 82 square mile watershed is controlled by jurisdictions outside Rockdale County. The challenge facing these governments was, and is, to develop and implement a plan to maintain a high quality water supply source while also allowing continued economic and population growth in an area facing significant development pressure.

To develop more flexible standards than the State Environmental Protection Department’s 25% impervious cover rule, while still providing water quality protection, the governments in the watershed and the Atlanta Regional Commission committed to conduct and finance a watershed study and the development of a watershed management plan in 1991. The study recommendations included a 2020 land use scenario as well as options for the local governments in developing their own watershed protection measures.

Following the study’s completion, the participating governments signed an inter-governmental agreement in September 1995 creating the Big Haynes Watershed Council as well as a supporting Technical Advisory Committee to oversee enactment of study recommendations, review effectiveness of the watershed protection program, and to meet on mutual concerns. In 1999, the Watershed Council began a study of regional stormwater ponds through a federal grant that may eventually result in a demonstration project for regional ponds in the watershed. Big Haynes serves as a good model as to how local, regional, and state governments can cooperatively work to achieve specific water resource protection goals.

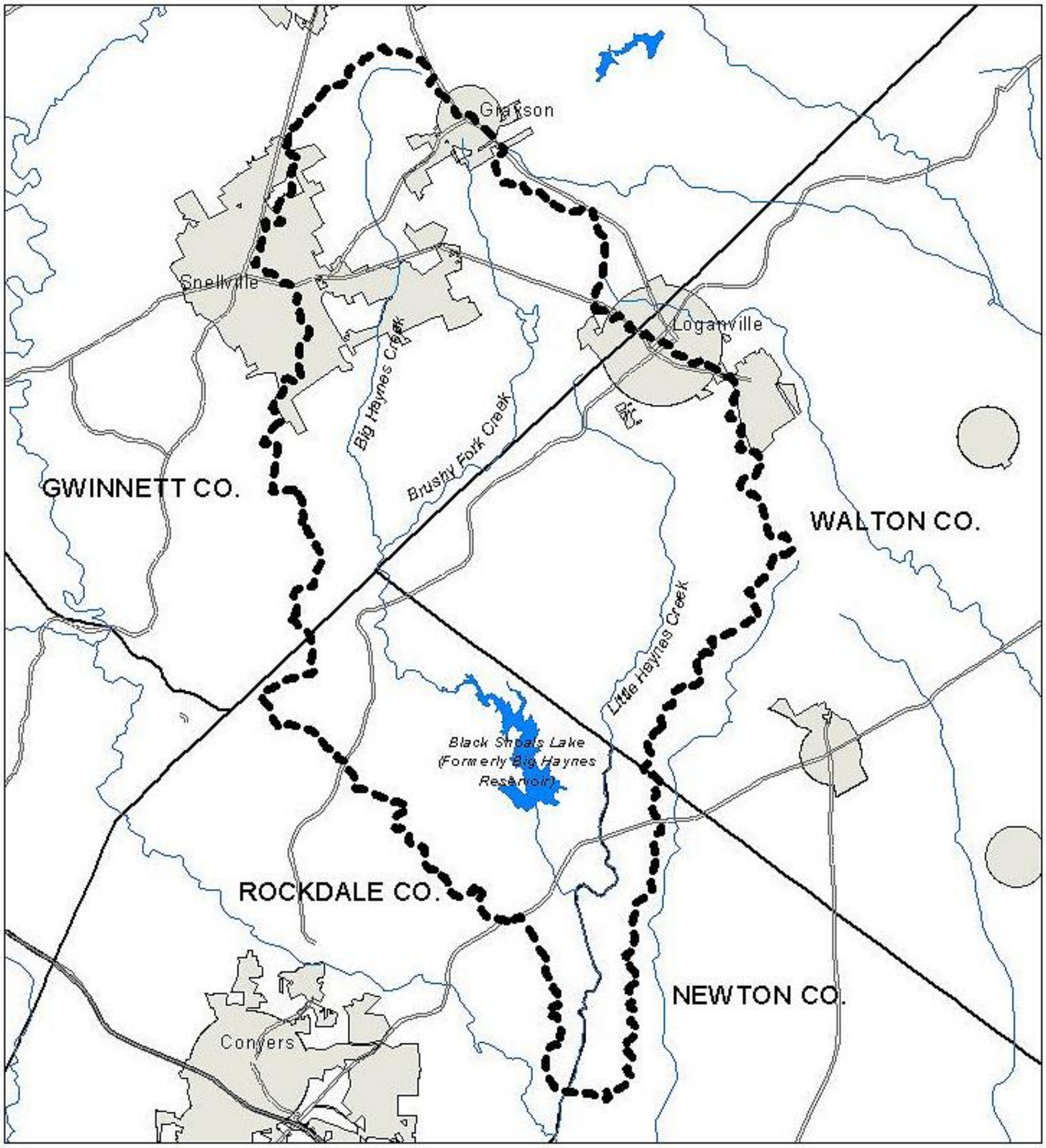

Figure 5-B.5 Big Haynes Creek Watershed
Source: ARC (2001)

5-B.5.0 OTHER WATERSHED PLANNING RESOURCES

The Center for Watershed Protection has numerous resources to assist with watershed planning and management. These resources can be accessed at the Center's website at:

http://www.cwp.org/Resource_Library/Watershed_Management/index.htm

5-B.6.0 CASE STUDIES

5-B.6.1 Henrico County Regional Stormwater Management Plan

Henrico County's regional/watershed plan for stormwater management is a very good example of how a community can develop alternative approaches to comply with state stormwater management requirements. Several particular features exemplify the kinds of flexibility that may be achieved in such plans:

- The County designated its urban/commercial corridors as Intensely Developed Areas. New development or redevelopment occurring within these areas is not required to have on-site stormwater management practices, due to the high level of imperviousness and high cost of land typical of these sites. Instead, the developers are allowed to pay a fee-in-lieu of an amount calculated to cover the cost of treatment elsewhere that will achieve an equivalent amount of pollutant (phosphorus) reduction.

- The County uses funds collected from these fees to do one of two things: (1) build regional-scale stormwater management facilities (typically ponds); or (2) restore degraded stream corridors, using natural channel design techniques (a la David Rosgen) and creating new or expanded riparian forest buffers – often with level spreaders installed to ensure sheet flow through the buffers – adjacent to the County's stream system. This latter strategy aims at establishing a natural stream system that will convey storm flows without damage to the stream's structure or streambank erosion, which improves the eco-health of the streams. By reducing sediment loads from these streams, the County expects to also reduce a sufficient amount of attached phosphorus to achieve the equivalent levels of TP-reduction needed to comply with the state regulations.

- Developments everywhere in the County still must comply with water quantity requirements, to assure that flows discharged from development sites do not erode natural receiving channels or create nuisance flooding.

- Developments outside of the commercial corridor zones must, of course, provide traditional on-site stormwater management practices to achieve the water quality and water quantity requirements in the state regulations.

Of course, an important key to making a plan like Henrico's work well is the timing of the installation of the regional-scale BMPs and stream restoration/buffer projects. Simply allowing developers to pay into a fund that continually grows – without expending the funds in a timely manner to construct the offset measures – does not solve the stormwater problems. In fact, it allows more problems to occur during the waiting period. Prior to approving watershed plans, the DEQ and the Board will expect localities to show how they will avoid this risk and assure timely implementation of offset measures.

Ideally, a community should identify sites for such regional facilities and prioritize stream restoration projects as part of the watershed plan. Then, through a bond mechanism or other up-front funding, the community should construct offset measures fairly early in a watershed's development, using the collected fees-in-lieu to repay the bond or other debt obligations.

It is also possible for communities to establish Stormwater Utilities (§ 15.2-2114, Code of Virginia), charging local citizens service fees as they do for sewage and water treatment services, trash collection and recycling. The Stormwater Utility could be associated with the watershed plan, and some of the collected funds might be used to construct and maintain the offset BMPs.

5-B.6.2 Chesterfield County's Swift Creek Watershed Stormwater Management Plan

Figure 5-B.6. Swift Creek Reservoir

The Swift Creek Reservoir was constructed in 1965 as a public water supply for Chesterfield County, Virginia. The 12 million gallon per day capacity Addison-Evans Water Treatment and Laboratory Facility provides on average 7.5 million gallons per day of drinking water to the County. The reservoir is a 1,700-acre impoundment containing approximately 5.2 billion gallons of water. The Swift Creek Reservoir Watershed is located in the northwest part of the county and encompasses 61.9 square miles. Its headwaters are located in Powhatan County. The watershed is divided into the following subwatersheds, based on its tributary streams:

- Little Tomahawk Creek
- Tomahawk Creek
- Turkey Creek/Swift Creek
- Otterdale Creek
- Horsepen Creek/Blackman Creek/Deep Creek
- West Branch
- Dry Creek
- Fuqua Creek

Initiatives for the Protection of the Swift Creek Reservoir Watershed

Chesterfield County conducted an assessment of the conditions of the Swift Creek Reservoir Watershed in 1989. Three years later, the Board of Supervisors adopted goals to protect the Swift Creek Reservoir and established a Watershed Management Committee that included citizen and staff representatives. This committee was charged with identifying strategies and alternatives to protect the reservoir. Based on recommendations from the committee in 1997, the Board established, through ordinance, a phosphorus loading limit of 0.22 pounds per acre per year (lbs/ac/yr) for new residential development and 0.45 lbs/ac/yr for nonresidential development. These loading limits were established by setting a 0.05 milligrams per liter (mg/L) in-lake phosphorus limit and calculating an allowable annual phosphorus input load. The Board also directed staff to prepare a regional master plan that included a funding strategy requiring the land development industry to fund the construction of regional stormwater management facilities. Additionally, development within the watershed was to fund the maintenance of the regional facilities.

In 2000, the Board unanimously approved the Watershed Management Master Plan and Maintenance Program (regional plan). The regional plan was developed to meet the goals and strategies set forth in Watershed Management Plan of 1996 through the construction of a system of regional storm water treatment facilities. One of these facilities, the regional in-stream pond component, was to provide the greatest reduction of pollutants.

In January 2006, the use of regional in-stream ponds met with resistance from federal regulatory agencies. During a meeting with the regulatory agencies, staff was advised that the in-stream regional pond component would not receive permitting and any future regional facilities would require off-line construction.

Modifications to the Watershed Master Plan

The regional in-stream pond component would have provided the greatest portion of storm water quantity and quality control for the protection of the reservoir. The inability to use this type of treatment, due to regulatory restrictions from federal agencies, greatly impacts the plan's performance. Staff has identified a framework of tasks and steps needed to modify the plan to meet the regulatory challenges and to provide opportunities to further protect the reservoir.

The modifications can be grouped into three main tasks:

- Requiring new construction to address storm water management on-site;
- Acquiring additional detailed information on current and future land-use phosphorus contributions; and
- Modifying the Watershed Master Plan.

Storm water pollution is directly related to the amount of impervious surface within a development. Conventional storm water controls collect runoff from these areas and convey the concentrated storm water, ultimately discharging it to a water body. Reducing impervious surface reduces the amount of runoff and limits the pollutant concentration resulting in the protection of county waters and the reservoir. The following will aid in reducing impervious surface starting with a review of existing county ordinances.

- **County Ordinances (Site Plan and Subdivision):** A preliminary review of county ordinances has identified several ordinances which could assist in the reduction of pollutant loads from new development. A more comprehensive review of the county's ordinances will be conducted to determine those areas where modifications may help to improve storm water runoff.
- **Preservation and Restoration of Natural Cover and Areas:** Retaining the existing natural conditions such as vegetation, soils and wetlands provides a natural and cost-effective way to manage storm water quantity and quality.
- **Low Impact Site Design Techniques:** LID is a site design strategy with the goal of maintaining or replicating the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape.
- **Using Natural Features for Stormwater Management:** Traditional storm-water systems are designed to collect, concentrate and convey storm flows efficiently away from the development. Natural drainage patterns tend to be ignored and replaced with structural controls. A nontraditional approach would seek to incorporate the site’s existing natural features. These could include natural drainage patterns, depressions, permeable soils, wetlands and vegetative areas. This would reduce the number of structural controls and provide for more natural storm water control through infiltration, pollutant filtration and maximizing on-site storm water storage.

The above measures will help to minimize the pollutant loads from future development by controlling the pollutants at the source. That portion of the future loads which can not be reduced as part of the on-site treatment and is in excess of the target load limit is referred to as the 'orphan load'. The reduction of load will need to be addressed through county run projects. The program will be executed through funds collected as part of the pro-rata fees. Many of these projects will be regional in nature and aimed at reducing identified pollutants loads.

Documents contain detailed information and presentations that have been provided to public and county officials regarding the watershed plan can be found on the County’s website at:

http://www.chesterfield.gov/content.aspx?id=2854

5-B.6.3 Norman Oklahoma Comprehensive Watershed-Wide Stormwater Management Plan

Editor’s Note: The Norman plan is included here as an excellent example of a very thorough, comprehensive watershed management plan incorporating numerous major stormwater management goals (Source: Stormwater Magazine, May 2010).

Like countless municipalities across the nation, the city of Norman, Oklahoma, has had to contend with increased flooding and erosion and diminished water quality resulting from urbanization. Home to the University of Oklahoma and a population of approximately 112,000, Norman seeks to address these problems, particularly a decline in water quality in Lake

Thunderbird, the city's primary source of drinking water. A recently completed Storm Water Master Plan (SWMP) will greatly facilitate Norman's efforts to reduce dangers associated with flooding, protect water quality, comply with federal and state stormwater quality regulations, enhance the environment, improve recreational opportunities, and outline funding options for related program activities.

Examining the Streams and Watersheds

Located in central Oklahoma, Norman has an annual average rainfall of nearly 35 inches and is prone to flash flooding. The city comprises an area of nearly 190 square miles, of which almost 30 square miles have undergone significant development to date. Population growth and greater urbanization have caused increased flooding, erosion, and various water-quality problems in the city's watersheds, particularly among urban streams.

Norman hired PBS&J to develop the SWMP in 2007. Shortly thereafter, the city created a Storm Water Task Force to help guide the city and PBS&J, as well as to provide one of several forms of public input used during the project. Members of the task force met regularly with representatives of the city and PBS&J to review progress and offer suggestions. In addition, the city requested public input through its Web site and held six public meetings to solicit input directly from the public.

Primary goals developed during the creation of the SWMP included reducing flood dangers, improving water quality, enhancing the environment, and advancing recreational opportunities. During the development of the SWMP, existing sources of information and data were relied on as much as possible. However, additional information needed to be collected to provide a solid foundation for the plan. Although Norman's 15 major watersheds were subdivided into 36 tributary watersheds and further subdivided into 665 subareas for more detailed study, some were analyzed to a greater degree than others. Analyses pertaining to assessments of watersheds and streams, stream flooding, and stream erosion were conducted in accordance with one of four "levels" of study.

Figure 5-B.7. Streambank erosion along the Little River

Figure 5-B.8. Fallen trees and debris resulting from stream erosion block a section of Imhoff Creek

A level 1 study entailed conducting detailed examinations of hydrology, hydraulics, and floodplain mapping for certain streams and their respective watersheds. New hydrologic and hydraulic models were developed for these streams based on the most recent topography and aerial coverage available from the city, field surveys of road crossings and selected cross sections, field reconnaissance visits, and detailed delineations of drainage areas, land use coverages, impervious cover, soils, and updated US Geological Survey intensity-duration-frequency rainfall relationships. These models then were used to depict existing and future build-out flooding conditions, along with the improved flooding conditions expected to result from the proposed solutions. Watershed assessments, meanwhile, were developed using field reconnaissance as well as city GIS files to obtain data pertaining to such details as land use (or zoning), impervious cover, floodplain locations, soils, and other watershed data. Finally, stream assessments were developed using extensive field reconnaissance visits and the city's aerial and topographic data to document stream channel and overbank flow conditions and locate and characterize stream erosion sites.

A level 2 study was the next most detailed. Similar to a level 1 study in most respects, a level 2 study used hydrologic and hydraulic models from studies and study updates previously submitted to, and accepted by, FEMA. Generally, the FEMA models were reviewed and modified only if obvious errors were apparent. Like their level 1 counterparts, the models were used to depict existing and future build-out flooding conditions, along with the improved flooding conditions expected to result from the proposed solutions.

Level 3 and 4 studies generally were used for stream reaches that have more than 40 acres of drainage area and are not located in Norman's urban core, where small drainage systems primarily consist of storm sewers and manmade channels. Level 3 and 4 streams and their watersheds were subject to general studies regarding their hydrology, hydraulics, and floodplain mapping. Watershed assessments were developed using city GIS files for land use (or zoning), floodplains, soils, and other watershed data. Stream assessments were limited to describing general characteristics of the particular stream reaches considered, based on very limited field reconnaissance and city GIS data. Although level 3 and 4 reaches were studied in the same manner, level 3 streams have been identified by the city as the next in line for detailed studies when funds are available in the future.

In summary, hydrologic analyses and watershed assessments were performed for 307 square miles of watershed area, while hydraulic analyses and floodplain mapping were developed for almost 400 stream miles, which included 59 miles along detailed (levels 1 and 2) streams and 333 miles along general (levels 3 and 4) streams. Additionally, 69 field-documented stream reach assessments were performed in level 1 and level 2 watersheds, while more general assessments using available data were performed for 635 stream reaches city-wide.

Identifying Stormwater Solutions

Stormwater problems were grouped into four categories—stream flooding, stream erosion, water quality, and local drainage—to assist in understanding the overall magnitude of each problem type. Fifty-nine problem areas were identified, spread over a large swath of the city. Complicating matters, many of the problems occur on property lacking sufficient drainage easements or rights of way. As a result, the estimated costs for solutions in such locations include expenses related to purchasing such easements or rights of way. **Table 5-B.8** shows the number of problem areas in watersheds subjected to level 1 or 2 studies, as well as the estimated costs of the proposed solutions. Although solutions for stream flooding and erosion were proposed only for level 1 and 2 stream reaches, solutions related to water quality are more programmatic and, therefore, apply more broadly across the city as a whole.

As noted earlier, the combined 59 solutions recommended as part of the SWMP have an estimated cost of nearly $83 million. Of this amount, nearly 90% is related to solutions in five urban watersheds: Bishop Creek, Brookhaven Creek, Imhoff Creek, Merkle Creek, and Woodcrest Creek. Stream flooding occurs in several locations in these watersheds, and stream erosion frequently destabilizes the mid and lower stream reaches in these watersheds.

Table 5-B.8. Summary of Proposed Norman, Oklahoma Stormwater Projects

Watershed	Stream Flooding		Stream Stabilization		Local Drainage		Watershed Total Cost	Percent of City Totals
	No.	Costs	No.	Costs	No.	Costs		
Bishop Creek	6	$5,347,808	6	$1,817,248	5	$4,720,055	$11,885,111	14.4
Brookhaven Creek	4	$2,613,904	4	$2,106,735	3	$1,278,962	$5,999,601	7.3
Clear Creek	-	-	-	-	1	$1,794,023	$1,794,023	2.2
Canadian River	-	-	-	-	1	$400,645	$400,645	0.5
Dave Blue Creek	2	$1,786,733	-	-	-	$1,786,733	$1,786,733	2.2
Imhoff Creek	9	$24,439,559	2	$6,816,509	1	$43,717,155	$43,717,155	53.0
Little River	1	$305,233	1	$123,682	-	$428,915	$428,915	0.5
Tributary G to Little River	1	$992,182	-	-	-	$992,182	$992,182	1.2
Woodcrest Creek	3	$3,167.165	1	$110,965	-	$3,278,130	$3,278,130	4.0
Merkle Creek	4	$8,856,558	-	-	-	$8,856,558	$8,856,558	10.7
Rock Creek	3	$3,135,111	-	-	-	$3,136,111	$3,136,111	3.8
Ten Mile Flat Creek	-	-	-	-	1	$255,326	$255,326	0.3
Citywide Totals	**33**	**$50,645,253**	**14**	**$10,975,139**	**12**	**$20,910,098**	**$82,530,490**	**100.0**

To the extent feasible, integrated solutions were developed to address stormwater issues as comprehensively as possible. Generally, problems in a given location tended to take the form of one major type, such as stream flooding. However, even in locations in which only one problem predominated, the proposed solution was developed in such a way that it would also improve other stormwater aspects. For example, a conceptual solution for addressing stream flooding would be designed in such a manner so as to protect the stream from future erosion. Whenever possible, bioengineering and natural channel design concepts and techniques were incorporated to improve or protect a stream's environmental integrity. Meanwhile, the adopted solutions target future watershed development conditions projected in the city's 2025 Land Use Plan. In this way, solutions will better help the city address future stormwater needs and provide a more complete "blueprint" for managing stormwater.

Figure 5-B.9. This reach of Shoal Creek was restored Using bioengineered techniques and natural materials

Of the 59 projects proposed as part of the SWMP, 33 would mitigate stream flooding through the use of such approaches as bioengineered stream modifications, storm sewer improvements, and stormwater detention. Of those 33 projects, 26 are intended to address flooding of structures. All told, the 26 projects would remove 652 structures from the 100-year baseline floodplain. Of the 33 projects for mitigating stream flooding, 29 would include upgrades to road crossings that are routinely overtopped during flood events. In fact, 36 road crossings would be protected to design levels. Although an effort was made to minimize property buyouts, 12 of the 33 projects would rely on buyouts of flood-prone structures. The SWMP identifies 62 properties as possible candidates for a buyout.

The level of protection for most stream flooding solutions varied somewhat. However, improvements associated with channel capacity and roadway bridge openings used projected 100-year baseline (future) peak discharges, while roadway culvert openings used 50-year peak flows. Exceptions occurred in special cases where 10-year protection was judged to be preferred because of limited space and the costs associated with larger improvements.

Twelve projects called for in the SWMP would address local drainage problems, while another 14 projects would use stabilization measures to address stream erosion. Overall, the SWMP identifies 10,050 feet of eroding streams to be stabilized by a combination of techniques, including channel grade control, streambank armoring, slope flattening, and bank toe protection. Various combinations of materials were recommended for achieving these techniques, including rock riprap, erosion protection fabric, geogrids to hold certain specific structures together, and select vegetation.

General cost estimates for each recommended project solution were developed using unit costs and estimated quantities for the construction bid items required to construct the respective projects. The SWMP also includes cost estimates for new drainage easements and/or rights of way needed to ensure construction of project improvements on property owned by the city or made available through city easements. Costs were obtained from city staff based on historical costs, location of the problems, and adjacent local land use.

Another important element of the SWMP was the integration of the recommended stormwater solutions with proposed greenbelt routes. During development of the SWMP, Halff Associates, a member of the consultant team, prepared a plan for greenbelt trails in the city. Throughout the project, team members coordinated to ensure that stormwater projects could be integrated with greenbelts whenever possible. During the design effort for any particular project, its integration with greenbelts can be considered further and incorporated into the project if the city desires.

Prioritizing the Solutions

Two critical aspects of the SWMP involved prioritizing the solutions and developing optional financing methods to help the city decide which projects to conduct first and how to finance them. The system developed for prioritizing solutions evaluates, scores, and ranks each one, in terms of its ability to solve the problem under consideration, provide for public safety, provide sustainability, utilize funding advantages, positively affect neighborhoods and the environment, and benefit other functions such as transportation. This prioritization identifies the most critical projects for addressing the stormwater needs in Norman and provides an important tool for the city as it determines the order in which solutions might be implemented and how they might be financed.

Each prioritization factor was given a weight based on its importance. Factors were grouped and classified in four categories. The factors in the most important category were given a weighting of four, the factors in the second category were given a weighting of three, the factors in the third category were given a weighting of two, and the factors in the fourth category were given a weighting of one. The various factors are shown in **Table 5-B.9** below along with scoring examples for hypothetical projects.

To evaluate a project using this prioritization “matrix,” each factor then was assigned a project-specific rating between zero and three, with three being the highest, two being moderate, one being low, and zero indicating the degree to which the factor had relevance, or a positive impact on, the project. Once each factor was rated for a project, the factor weighting was multiplied by the rating to give a factor score. The individual factor scores were then totaled to give a total prioritization score for the project. A higher the score means the subject project has greater importance. This process was followed for each identified project. Once project prioritization scores were obtained, the project rankings were then compared on the basis of watersheds, wards, and citywide.

Table 5-B.9. Norman, Oklahoma, Watershed Plan Project Prioritization Scoring Sheet

Prioritization Ranking Factors	Ranking Factor Weight	A Road Drainage Ditch		Wet Creek Buyouts		Maximum Possible Score	
		Project-Specific Score	Project-Specific Weighted Score	Project-Specific Score	Project-Specific Weighted Score	Project-Specific Score	Project-Specific Weighted Score
Public Safety	4	3	12	3	12	3	12
Flood, erosion, and water quality significance	4	1	4	2	8	3	12
Engineering economy (good benefit/cost relationship)	4	2	8	3	12	3	12
Potential for recreation/open space/connectivity for linear parks	4	2	8	3	12	3	12
Sustainability or low operations and maintenance cost	3	1	3	3	9	3	9
Environmental enhancement	3	1	3	3	9	3	9
Funding sources (leverage of participants' available funds)	2	2	4	2	4	3	6
Beneficial neighborhood impacts	2	1	2	1	2	3	6
Degree of economic impact on local businesses	2	2	4	3	6	3	6
Dependency on other projects	1	0	0	1	1	3	3
Improved economic development/redevelopment potential	1	3	3	2	2	3	3
Mobility or effects on transportation system	1	3	3	0	0	3	3
Time to implement or construct	1	2	2	1	1	3	3
Ease of permitting	1	1	1	3	3	3	3
Project Total Specific Score			57		81		99

Protecting Water Quality in Lake Thunderbird

Individual projects aside, the SWMP also evaluated how Norman should protect and improve water quality throughout the city and especially in its drinking water supply, Lake Thunderbird. The Oklahoma Department of Environmental Quality (DEQ) has designated Lake Thunderbird as a sensitive water supply lake. However, elevated levels of chlorophyll a – an accepted measure of algal content – have been found in the reservoir, prompting the Oklahoma DEQ to add Lake Thunderbird to its list of impaired water bodies, in accordance with Section 303(d) of the Clean Water Act.

Unless significant steps are taken to reduce the influx of pollutants to the lake, further degradation of the lake's water quality can be expected as land development progresses in the Lake Thunderbird watershed. Current high loadings of nutrients – the main factor contributing to algal growth in the lake – are only expected to increase with urbanization. The prospect of more algal growth includes an increased threat of toxins being produced in the lake from algal masses, exacerbating taste and odor problems with drinking water and decreasing recreational opportunities. Although other urbanized or urbanizing areas to the north contribute significant stormwater to the lake, Norman is the largest municipal area draining to Lake Thunderbird. In fact, roughly half of the area that drains to the reservoir is in the city limits. Therefore, the SWMP includes recommendations for management practices that can help protect water quality in Lake Thunderbird.

Because limiting nutrient loadings will require a combination of structural and nonstructural measures, the SWMP included recommendations for particular approaches expected to provide the greatest benefits. Although implementing controls in previously developed areas would be difficult, using such controls in future developments will greatly assist Norman in its efforts to improve water quality in Lake Thunderbird.

Measures recommended in the SWMP include stream planning corridors (SPCs), various structural and nonstructural controls, fertilizer use education, fertilizer use controls, a continuation of present development density controls, and low-impact development practices. If implemented properly, these management practices will significantly assist in preserving and protecting the Lake's water quality and the city's primary water source.

The SWMP proposes the dedication of SPCs within drainage areas greater than 40 acres in watersheds that contribute to Lake Thunderbird. SPCs are defined as the area of land along both sides of a stream or natural drainage corridor that encompasses the area projected to be inundated by the 1% probability flood (i.e., the 100-year floodplain) in any given year, assuming full build-out watershed conditions. As proposed, an SPC could possibly include an additional buffer width to aid in further filtering runoff and providing environmental protection of stream riparian areas. Such corridors are particularly useful in headwater areas, where the features have the best opportunity for filtering runoff and facilitating infiltration. Of course, the city will have to make certain legal and political changes before SPCs may be implemented.

Evaluating Structural and Nonstructural Controls

Norman already is implementing programmatic water-quality solutions in its urbanized areas as part of efforts to comply with the Oklahoma DEQ's permit requirements for municipal separate storm sewer systems (MS4s). As a supplement to these efforts, the city will need to require that new developments incorporate certain structural and/or nonstructural water-quality controls.

In general, the SWMP recommends that Norman require structural stormwater controls in the same manner and locations as required for stormwater detention throughout the city. Such controls include extended detention basins, wet ponds or retention basins, filtration basins, porous pavement, and grassed swales. These structural controls can be constructed in conjunction with stormwater detention facilities in most instances. Because of maintenance costs and concerns regarding public safety and nuisance considerations, the city plans to encourage the use of dry detention facilities rather than wet detention facilities in most, but not all, cases.

In terms of nonstructural controls, the SWMP recommends that the city continue to ensure that the minimum control measures conducted as part of the MS4 program be met. Such measures include fertilizer application controls, street sweeping, oversight of septic system installation and operation, and area-specific development density limitations.

The SWMP recommends new ordinance requirements pertaining to structural and nonstructural controls. For example, the SWMP suggests that Norman require that water-quality facilities be constructed to capture and treat runoff from all proposed developments exceeding 1 acre (or some smaller size selected by the city). The runoff "capture and treatment volume" should be set to 0.5-inch of runoff from the development area, unless otherwise specified for a special condition. Furthermore, the SWMP recommends that the city allow and encourage developers to use low-impact development techniques such as rain gardens and biofilters to meet a portion or all of their water-quality control requirements, assuming that the developers provide sufficient technical justification for the techniques.

Presenting Financial Options

It is anticipated that many of the recommended solutions will be included in a capital improvement program (CIP) to be implemented by the city. Funding for this CIP program and other stormwater costs are anticipated to come from a stormwater utility that the city of Norman proposes to establish. If approved by city voters, stormwater utility fees will be based on the amount of impervious cover on each respective property within the city, regardless of land use type. In fact, the SWMP serves as a basis for the creation of the utility.

Financial analyses were performed to determine how best to meet the funding needs for the programs and activities associated with the SWMP. The revenue required for the stormwater management activities and improvements outlined in the SWMP can be divided into several categories of need. These include needs for debt service, creation of a reserve fund less any non-operating revenues such as interest earnings, continued general overall operation and maintenance, shared city services, minimum control measures for stormwater MS4 regulatory compliance, enhanced maintenance for streams and stormwater detention facilities, trail construction, easements and rights-of-way acquisition, and stormwater capital improvement projects paid for with cash.

In addition to reducing funding requirements from a stormwater utility, the city decided to propose funding a portion of the stormwater capital improvements with general obligation bonds to provide necessary projects more quickly in areas of critical stormwater needs.
Three rate options were developed to fund the stormwater capital improvements using the split between general obligation bonding and stormwater utility rates over a 20-year program, as defined by the city. As shown in **Table 5-B.10** below and consistent with the CIP costs for proposed solutions, the total 20-year CIP needs in 2008–2009 dollars were estimated to be approximately $83 million. To cover these costs, three options for financing this portion of the overall program were developed, with varying amounts of general obligation bonding and stormwater utility user fees.

Table 5-B.10. Three Rate Options: Fiscal Year 2008-2009 Dollars (Uninflated)

Item	Option 1	Option 2	Option 3
Capital Improvement program (20-year period)	$83,000,000	$83,000,000	$83,000,000
Funding source: general obligation bonds	$30,000,000	$38,500,000	$40,000,000
Funding source: Stormwater user rates (Pay-go) financing	$53,000,000	$44,500,000	$43,000,000
Total	$83,000,000	$83,000,000	$83,000,000
Program period, years	20	20	20
Capital Improvement projects funded by rates, per year	$2,650,000	$2,225,000	$2,150,000

Considering all revenue requirements identified, monthly stormwater rates for a median single-family home having approximately 3,100 square feet of impervious cover were determined to be $6.26, $5.85, and $5.78 for options 1, 2, and 3, respectively.

Conclusion

Although the SWMP is complete, the city of Norman still must decide how to implement and finance the plan's recommendations. This process will require the sustained involvement of stakeholders and approval of a stable funding source by Norman's citizens, along with efforts by the city to continue to refine its future needs and goals regarding stormwater and watershed protection. Using the SWMP as a solid foundation, Norman will be able to satisfy its regulatory requirements, enhance recreational opportunities, protect the environment, and meet local challenges relating to flooding, stream erosion, drainage problems, and water quality.

5-B.6.4 Big Darby Accord Watershed Master Plan, Columbus, Ohio

The Big Darby Accord consists of local governments within the Franklin County, Ohio area of the Big Darby Creek watershed (see **Figure 5-B.10** below). The mission of the Big Darby Accord is to cooperatively develop, implement and enforce a multi-jurisdictional plan and accompanying preservation and growth strategies designed to:

- Preserve, protect and improve, when possible, the Big Darby Creek watershed's unique ecosystem by using the best available science, engineering and land use planning practices;
- Promote responsible growth by taking measures to provide for adequate public services and facilities and promote a full spectrum of housing choice, as well as adequate educational, recreational and civic opportunities for citizens of each jurisdiction and for Central Ohio;
- Create a partnership that recognizes the identity, aspirations, rights, and duties of all jurisdictions and that develops methods of cooperation among the partners through means which include the cooperative use of public services and facilities; and
- In development of the plan, capitalize on the results of other efforts by considering local comprehensive plans and zoning efforts, as well as the work of other policy teams and advisory committees aimed at environmentally-sensitive development.

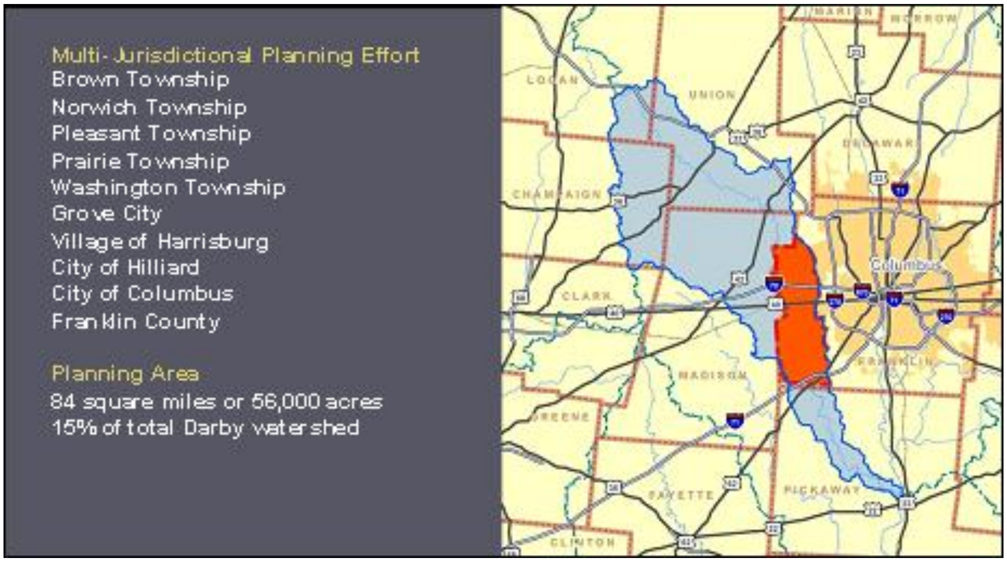

Figure 5-B.10. Big Darby Creek Watershed Planning Area
Source: AECOM

Leading up to establishment of the Big Darby Accord, the watershed environment had displayed long-trending evidence of decline – severe in some places – in biological diversity of the aquatic ecosystem. Stream monitoring had revealed impairments involving several key water quality parameters. Some watercourses had severe physical degradation and, in some cases, loss of functional components of the drainage system. The land development pattern within the study area had evolved over time as the City of Columbus grew and annexed land.. Along the eastern boundary of the study area and near Interstate 70, development was more dense and reflective of suburban patterns.

The remainder of the study area was mostly rural in nature, including agricultural lands and low-density residential development on large lots. Land use and zoning policies in place at the time were promoting an additional 20,000 households in the study area, more than doubling the existing number of households. The Accord Plan proposed a similar level of development, but in a pattern that would be more manageable, sustainable, and environmentally sensitive. The accord process itself established a new regional-scale approach to managing development within the watershed. A number of drivers provided the framework for the creation of a regional watershed plan:

- The Darby watershed was home to 38 state- and federally-listed threatened or endangered aquatic species when the Plan was initiated;
- The Ohio EPA (OEPA) had declared the Darby watershed impaired in 2004, which paved the way for development of a TMDL in 2006.
  - The OEPA was developing a new water quality management plan that included water quality provisions for Big Darby Creek.
  - Modeling conducted by OEPA as part of the TMDL process for the entire watershed set aggressive water quality targets to reduce TSS by 95% and Total Phosphorus by 82%.

- Previous state and local planning efforts and initiatives helped to drive the focus on water quality; and
- Public water and sewer services, provided predominantly by the City of Columbus throughout the region, were approaching capacity; and
- Development rights under the existing zoning were recognized as a baseline for future development.

The challenge was to create a plan that would achieve the new water quality standards and address other environmental concerns, while not eliminating all land development. The process (see **Figure 5-B.11**) took several years of studies, planning, and negotiation among participating jurisdictions and stakeholders. The final Big Darby Accord Watershed Master Plan, now adopted, was heavily focused on implementation, since none of this would work unless all the jurisdictions involved agree to work together and uphold the same standards. The necessary cooperation was largely achieved in response to a three-year building moratorium imposed in the study area by the Columbus water and sewer authority, to be ended only when a regional plan was in place. The process involved the following planning activities:

- Analysis of existing conditions to understand the existing environmental constraints. This step included GIS analysis and an environmental resources sensitivity analysis to inform the development industry of appropriate land use alternatives;
- Development of a conservation strategy based upon the environmental sensitivity analysis and existing natural resources. The conservation strategy laid the foundation for land use recommendations;
- Hydrological modeling of land use alternatives to determine the impact on water quality measured in terms of pollutant loading (sensitive to project land use changes);
- Evaluation of potential pollutant loadings, including groundwater pollution potential;
- Creating a solid foundation of information and data upon which to develop policies and implementation actions; and
- Conducting extensive public outreach, with frequent stakeholder group meetings and citizen focus groups.

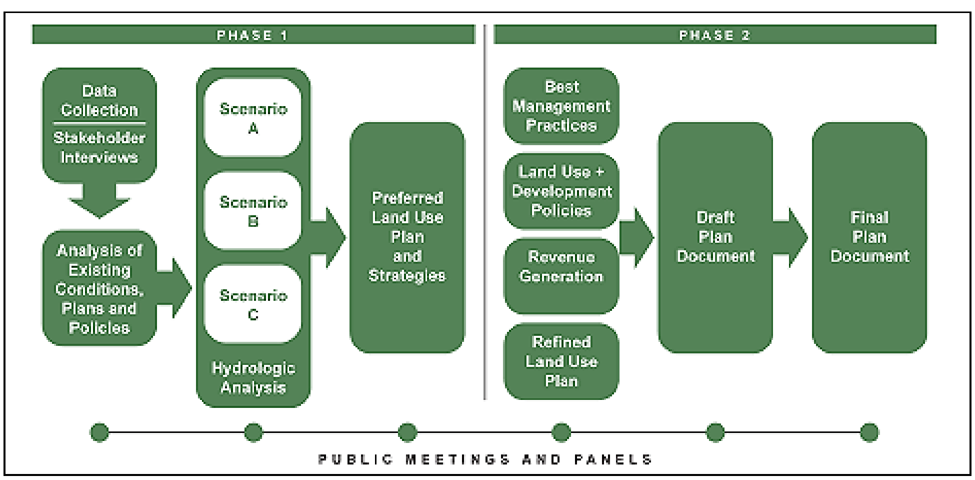

Figure 5-B.11. Big Darby Accord Watershed Planning Process Diagram
Source: AECOM

The initial planning activities culminated in an environmental sensitivity analysis of lands in the watershed. This analysis identified over 32,000 acres as having some level of environmental significance. The analysis reinforced the importance of stream corridors in the area, and ultimately it became the foundation for the conservation strategy that was a fundamental part of the plan.

This led to development of the conservation strategy for the watershed (**Figure 5-B.12**) aimed at protecting significant natural resource areas. The Plan sets forth an aggressive goal of protecting 25,000 acres of land within a comprehensive green infrastructure network. Approximately 7,000 acres of land were already subject to some type of protection. The areas were prioritized and divided into three tiers, with the understanding that new zoning policies would be needed to adequately protect these lands.

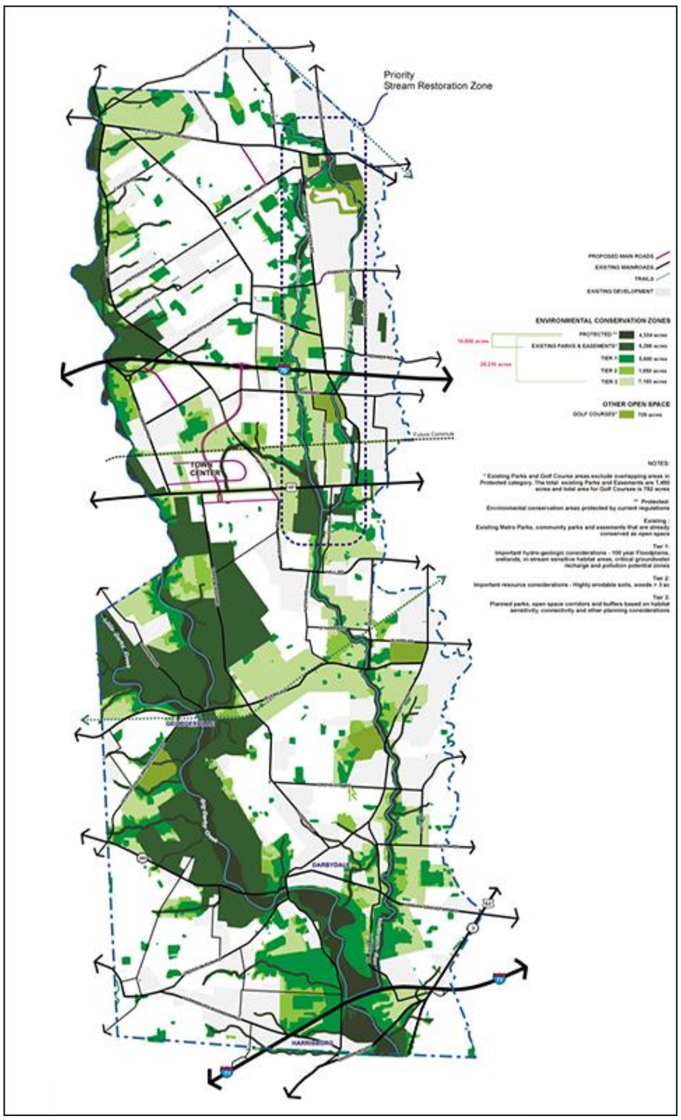

Figure 5-B.12. Big Darby Watershed Conservation Strategy
Source: AECOM

- Tier 1 (5,600 acres): First priority for acquisition or other land protection programs (e.g., floodplains, wetlands, groundwater recharge areas, pollution potential zones, etc.);
- Tier 2 (1,850 acres): Second priority for acquisition (e.g., highly erodible soils, large wooded areas, etc.); and
- Tier 3 (7,160 acres): Third priority, for land use easements and conservation development (e.g., connections, habitat corridors, linkages, trails, etc.),

The planning analysis showed that approximately 49,000 people lived in the study area, but at build-out (based on the existing land use policies) the population would surge to 100,000 in a very low-density development pattern. Three alternative development scenarios (see **Figure 5-B.13**) were developed, using the existing "by right" policies as a baseline target. Each alternative explored different land use patterns and densities to accommodate projected growth and had varying infrastructure considerations (e.g., water/sewer, etc.):

- Option A: Continue with existing policies (very low density development)
- Option B: Concentrate development along a new corridor
- Option C: Cluster development in village centers

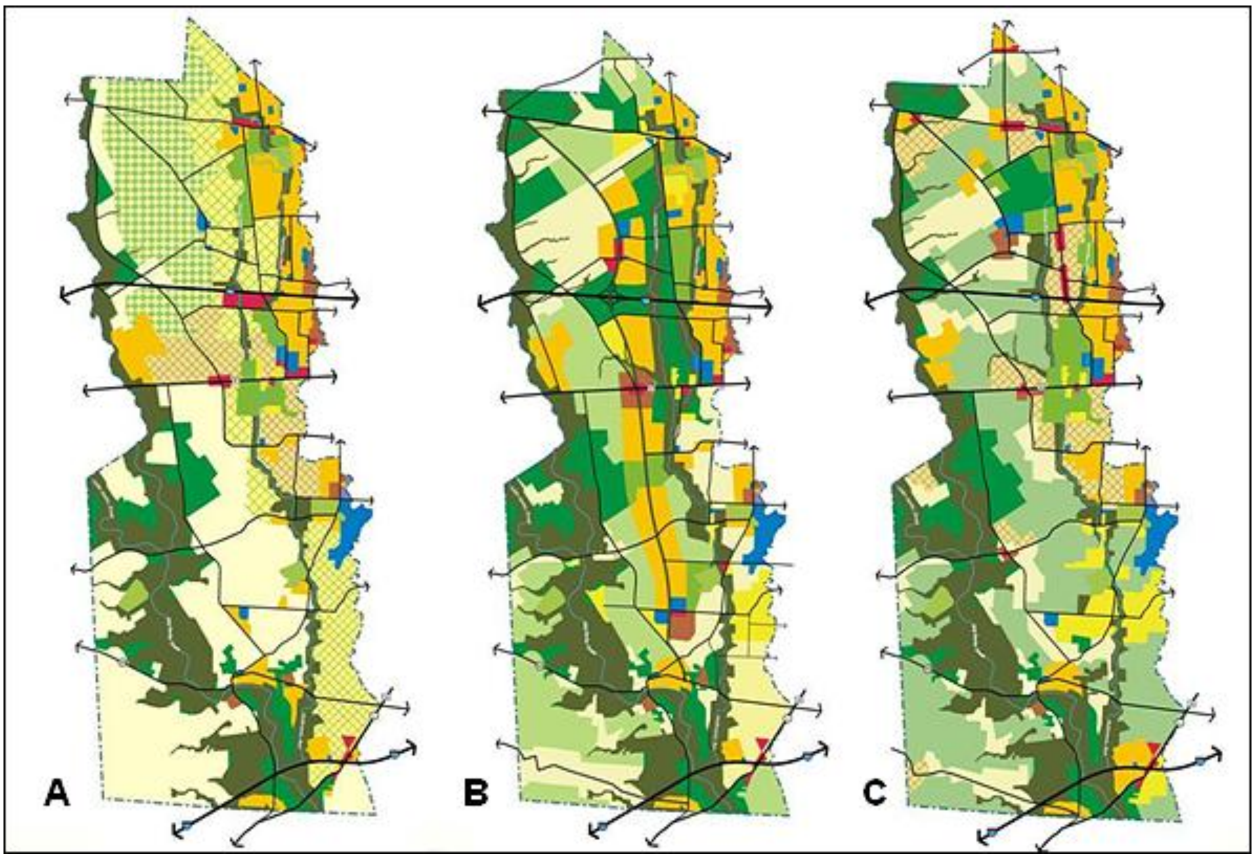

Figure 5-B.13. Three Alternative GIS Land Use Scenarios for Big Darby Watershed Plan
Source: AECOM

Using mutually agree-upon zoning classifications, land uses were determined for each option and fed into a hydrological model (Soil and Water Assessment Tool, or SWAT) to evaluate the impacts each scenario (and associated land uses) would have on water quality. Additional modeling revealed that a change in land use policies would help to accomplish the various goals of the plan while allowing the use of BMPs that could potentially achieve lower pollutant removals than the TMDL required. However, it became clear that BMPs and, in many cases, treatment trains of BMPs would be necessary to achieve the water quality targets.

The final preferred watershed land use plan included many positive elements growing out of the extensive planning and analysis as well as negotiations among stakeholders and local governments. Characteristics of the plan included the following:

- Conservation development:
    - Clustering of units allows environmentally responsible development
    - Requires maintaining 50% open space in the watershed within each development
- Property owners have options:
    - Plan continues to allow for the existing level of development/use
    - Owner can develop per the plan and existing zoning and meet applicable environmental standards, BMPs, and development regulations
    - Alternatively, the owner can sell the property's development rights and continue to live, farm, etc. on the land (conservation easement placed on the property)
    - Owner can sell the property
- Character of development:
    - Mix of uses
    - 5,000 additional dwelling units within a newly identified town center
    - Integrated parks and green spaces
    - Comprehensive stormwater drainage/treatment system, incorporating regional BMPs
    - Use of Low Impact Development (LID) techniques and practices
- Town Centers:
    - Focuses development in appropriate the location
    - Lowers environmental sensitivity and impacts
    - Capitalizes on existing infrastructure
    - Provides full spectrum of housing prices
    - Allow extension of sewer lines without annexation
    - Allows for the use of central sewer service, avoiding the need for septic systems
- Balanced conservation and growth
    - Protects environmentally sensitive areas by directing development away from those resources
    - Requires BMPs to achieve the TMDL limits
    - Encourages LID
    - Recommends a water quality monitoring program
    - Encourages regional stream restoration

To move the plan forward to implementation, an advisory panel composed of members from each participating local government jurisdiction was established. The purpose of the panel is to guide local decision-making and to help establish revenue mechanisms that can fund land protection and water quality improvement programs within the study area. Land development will play a part in the funding effort. An earlier review of potential funding methods had helped build support for the plan's final policies.

The plan cost approximately $700,000 in consulting costs, as well as additional costs for the localities in staff time and public process expenses. The process took a year-and-a-half to complete, including time for stakeholder debate and local government negotiations. As a result of this process and its ongoing implementation, a new spirit of collaboration and cooperation is occurring in the region. Revised and coordinated zoning policies have been drafted, including conservation development and stream buffer setbacks. A draft Town Center Master Plan is under review (http://www.bigdarbyaccord.com/updates/towncenter.cfm). The revenue program is under development. New programs for open space and land conservation have been established. Finally, the county and the City of Columbus have entered into a utilities agreement. This plan demonstrated clearly that, while land use is inextricably linked to watershed health, plans need to go beyond land use to adequately protect watershed health.

For more information, visit the Big Darby Accord website at:

http://www.bigdarbyaccord.com/index.cfm

5-B.7.0 REFERENCES

Altman, Duke G. and Shawn O'Leary. May 2010. "Norman Plans Ahead." *Stormwater Magazine.* Forester Media, Inc. Santa Barbara, CA.

Atlanta Regional Commission (ARC). 2001. *Georgia Stormwater Management Manual*. Prepared by AMEC, the Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, and the Atlanta Regional Commission. Atlanta, Georgia.

Center for Watershed Protection (CWP). (1998). *Better Site Design: A Handbook for Changing Development Rules in Your Community.* Ellicott City, MD.

Connecticut Department of Environmental Protection (DEP). (1995). *Connecticut Stormwater Quality Planning: A Guide for Municipal Officials and Regional Planners (draft)*. Bureau of Water Management, Planning and Standards Division. Hartford, Connecticut.

Hanleybrown, Faye, John Kania, and Mark Kramer. (Jan. 26, 2012). *Channeling Change: Making Collective Impact Work*. Stanford Social Innovation Review. Stanford U., Palo Alto, CA. http://www.ssireview.org/blog/entry/channeling_change_making_collective_impact_work?cpgn=WP%20DL%20-%20Channeling%20Change

National Research Council (NRC). (2008). Water and Science Technology Board, Division of Earth and Life Studies. "Chapter 3 Hydrologic, Geomorphic, and Biological Effects of Urbanization on Watersheds." *Urban Stormwater Management in the United States*. Washington, DC: National Academies Press. 109+. URL: http://www.nap.edu/catalog.php?record_id=12465#toc

Novotny, V. (1995). *Nonpoint Pollution and Urban Stormwater Management*. Technomic Publishing Company, Inc. Lancaster, Pennsylvania.

Pennsylvania Association of Conservation Districts, Keystone chapter Soil and Water Conservation Society, Pennsylvania Department of Environmental Protection, and Natural Resources Conservation Service. (1998). *Pennsylvania Handbook of Best Management Practices for Developing Areas*, prepared by CH2MHILL.

Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE). (1992). *Design and Construction of Urban Stormwater Management Systems: Urban Runoff Quality Management (WEF Manual of Practice FD-20 and ASCE Manual and Report on Engineering Practice No. 77)*.